National Seminar

on

Maize for Crop Diversification under Changing Climatic Scenario

9-10 FEBRUARY, 2020

Organized by:

Maize Technologists Association of India

In collaboration with

ICAR-Indian Institute of Maize Research, Ludhiana &
Punjab Agricultural University, Ludhiana


FMC
An Agricultural Sciences Company
Your Progress,
Our Nature
Now, with a bigger family
Affinity®, Amadis®, Authority®, Authority® NXT, Benevia®, Cilpyrox, Coragen®, Critel®, Eltra®, Fermo®, Ferterra®, Galaxy®, Gamit, Gezeko®, Kivalo®, Marshal® & Talstar® are trademarks of FMC Corporation or an affiliate.

National Seminar

On

Maize for Crop Diversification under Changing Climatic Scenario

February 9-10, 2020

Maize Technologist Association of India

In Collaboration with

ICAR-Indian Institute of Maize Research, Ludhiana and

Punjab Agricultural University, Ludhiana

Souvenir and Book of Abstracts

Compiled and edited by

Dharam Paul Chaudhary
Shanti Devi Bamboriya
Abhijit K. Das
Pardeep Kumar
Sumit Kumar Aggarwal
Ramesh Kumar
Sujay Rakshit

Sponsors

Platinum sponsors

Gold Sponsors

Silver Sponsors

नरेन्द्र सिंह तोमर
NARENDRA SINGH TOMAR

सत्यमेव जयते

कृषि एवं किसान कल्याण,
ग्रामीण विकास तथा पंचायती राज मंत्री
भारत सरकार
कृषि भवन, नई दिल्ली

MINISTER OF AGRICULTURE & FARMERS' WELFARE,
RURAL DEVELOPMENT AND PANCHAYATI RAJ
GOVERNMENT OF INDIA
KRISHI BHAWAN, NEW DELHI

MESSAGE

I am pleased to learn that Maize Technologists Association of India along with ICAR- Indian Institute of Maize Research, Ludhiana and Punjab Agricultural University, Ludhiana is organizing a National Seminar on "Maize for Crop Diversification under Changing Climatic Scenario" at Ludhiana during 9-10 February, 2020.

Agricultural sciences have made significant breakthrough in making our country self-reliant in food production. With the advancement of modern farming system, many challenges like low profitability, increasing input costs, continuous depletion of natural resources etc. started troubling the agriculture sector and the farming community. To overcome these constraints, the country needs to focus on low water consuming and more beneficial high yielding crops. Maize is an important crop which has its wider utilization as poultry and animal feed, industrial raw material and food. Very less water is required to irrigate maize as compared to paddy crop. However, a large variation exists among different states in the matter of maize productivity. Although some pockets are capable to produce more than 10 tonnes per hectare yet the major area under the maize is still producing less than 2 tonnes per hectare.

Besides, climate change also poses a big challenge to all cropping systems. Maize-based cropping systems hold immense promise in this regard. To increase profitability of maize-based cropping systems, farm mechanization needs to be integrated. Scientists need to generate innovative ideas and develop newer strategies to deal with emerging issues and challenges in the overall dynamics of the maize ecosystem.

I believe, the congregation of maize scientists at Ludhiana is significant in more than one way. It will deal with issues of major challenges to the scientists, the government and the society alike. I am confident that deliberations made during the National Seminar would result in a concrete road map that will help us surmount a formidable road block and attain a major national objective of doubling the farmers' income in near future.

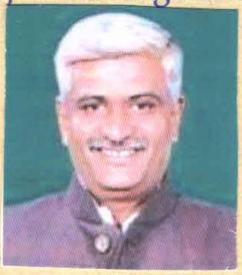
I congratulate the Maize Technologists Association and the co-organizers for holding this useful national seminar and wish the event a resounding success.

3/2/20

(Narendra Singh Tomar)

Office: 'G' Wing, Ground Floor, Krishi Bhawan, New Delhi- 110001, Tel.: 011-23782373, 23782327 Fax: 011-23385876
Resi.: 3 Krishna Menon Marg, New Delhi-110001, Ph.: 011-23794697 / 98, Fax: 011-23794696

गजेन्द्र सिंह शेखावत
Gajendra Singh Shekhawat



सत्यमेव जयते

स्वच्छ भारत
एक कदम स्वच्छता की ओर

जल शक्ति मंत्री
भारत सरकार
Minister for Jal Shakti
Government of India

21 JAN 2020

MESSAGE

Water is the scarcest natural resource so far agriculture is concerned. No doubt that progress in agriculture has contributed towards lifting the country from 'food deficit' country to 'food sufficient' country through the green revolution. However, the intensive agricultural practices have led to several adverse consequences as well. Besides impact on the ecology due to excessive use of agro-chemicals, over utilization of ground water for irrigation has led to fast depletion of ground water table. There is an urgent need to relook the cropping pattern and choose crops that are less water intensive.

In this regard maize has a special place. Water requirement of maize is one third of rice. Further, being a C4 plant is has higher productivity potential and widely used as food, feed, fodder and in recent past used as alternate bio-fuel besides its industrial use. It is one of the key in doubling farmers' income as it has highest productivity gain over last two decades. Maize can be integrated effectively with animal husbandry and as specialty corns in value chain development.

Under the changing climate, like all crops, maize is also going to face many challenges, both biotic and abiotic in nature. In this context a National Seminar on "Maize for Crop Diversification under Changing Climatic Scenario" being held at Ludhiana during 9-10 February, 2020 will be very informative and helpful to all the stakeholders.

I extend my best wishes to the organizers and the event a resounding success.

(Gajendra Singh Shekhawat)

जल शक्ति अभियान
संचय जल, बेहतर कल

Office : 210, Shram Shakti Bhawan, Rafi Marg, New Delhi-110 001
Tel: No. (011) 23711780, 23714663, 23714200, Fax : (011) 23710804
E-mail : minister-mowr@nic.in

ਕੈ. ਅਮਰਿੰਦਰ ਸਿੰਘ
Capt. Amarinder Singh

ਮੁੱਖ ਮੰਤਰੀ, ਪੰਜਾਬ
Chief Minister, Punjab

CMO/CONFI/2020/61

27-1-2020

MESSAGE

It gives me immense pleasure to know that the Maize Technologist Association of India along with ICAR-India Institute of Maize Research, Ludhiana and Punjab Agricultural University, Ludhiana is organizing a National Seminar on "Maize for Crop Diversification under Changing Climatic Scenario" at Ludhiana during 9 - 10 February 2020.

Punjab has been the cradle of Green Revolution in India, which has played a pivotal role in making the country self-reliant in food production. The role of hard working and resilient farmers of the state is laudable who turned the fortune of the nation by transforming it from a 'food deficit' to 'food surplus' country. However, the extensive cultivation of high yielding wheat and rice has overexploited the precious natural resources in terms of under-ground water and soil fertility.

In order to sustain the agricultural growth and to check the ever decreasing under-ground water, the state needs to diversify from rice cultivation to some other high yielding *kharif* crop. Maize being a top ranking crop worldwide, seems to be the most suitable alternative. Keeping in view the present scenario, this seems to be the right time to redraw our strategies to make significant enhancement towards large scale maize cultivation in the state. I hope that this National Seminar will provide a useful platform to the stakeholders from across the nation to address the emerging issues and challenges ahead besides helping in drawing a roadmap for better future of this crop. I hope the deliberations in the conference will result in valuable recommendations for betterment of agriculture in the state.

I wish the National Seminar a great success.

(Amarinder Singh)

Office : Punjab Civil Secretariat, Chandigarh-160001, Ph.: 0172-2740325, 0172-2743463(Fax)
Resi. : H.No. 45, Sector 2, Chandigarh-160001, Ph.: 0172-2741322, 0172-2746060(Fax)
e-mail : cmo@punjab.gov.in

कैलाश चौधरी
KAILASH CHOUDHARY

कृषि एवं किसान कल्याण
राज्य मंत्री
भारत सरकार
MINISTER OF STATE FOR AGRICULTURE
& FARMERS WELFARE
GOVERNMENT OF INDIA

सत्यमेव जयते

MESSAGE

I am pleased to know that a National Seminar on "Maize for Crop Diversification under Changing Climatic Scenario" is being organized at Ludhiana during 9-10 February, 2020, jointly by Maize Technologist Association of India, ICAR-Indian Institute of Maize Research, Ludhiana and Punjab Agricultural University, Ludhiana.

Genetic improvements in crop with improved production technologies made India not only self-sufficient in food grains but the country became a net exporter as well. However, stagnating yields, continuous mining of nutrients and ground water, and excessive use of natural resources have put pressure on production system that needs to become sustainable. In the present agricultural and climatic scenario, maize going to be an important crop for bright future in Indian agriculture. It has wider utilization in feed, food, starch industry and off late as a raw material for ethanol production. Moreover, maize stalk is being utilized for animal feeding. It seems to be very timely that Maize Technologist Association of India along with ICAR-Indian Institute of Maize Research, Ludhiana and Punjab Agricultural University, Ludhiana is organizing a National Seminar on "Maize for Crop Diversification under Changing Climatic Scenario" at Ludhiana during 9-10 February, 2020. I am sure that this National Seminar will deliberate on the issues so as to provide ways and means to make maize as a top ranking crop in Indian agriculture.

I wish the organizers and delegates a success in their deliberation during the National Seminar.

(Kailash Choudhary)

Dated 27.01.2020
New Delhi

Office : 199Q, Krishi Bhawan, New Delhi-110 001. Tel. : +91-11-23782343, 23388165 Fax : 23074190

परशोत्तम रूपाला
PARSHOTTAM RUPALA

सत्यमेव जयते

राज्य मंत्री
कृषि एवं किसान कल्याण
भारत सरकार
Minister of State For
Agriculture & Farmers Welfare
Government of India

D.O. No......871..MOS(A&FW)/VIP/2019-20/

Message

Introduction of high yielding photo-insensitive varieties responsive to farm inputs has no doubt increased the productivity of crops and helped in attaining self-sufficiency in food grain production. However, at the same time continuous depletion of natural resources due to intensive cropping system along with abiotic stresses like drought, cold, erratic rain and heat spells pose serious challenge for achieving sustainable production and productivity levels. Ensuring food and nutritional security for growing population along with protection of the natural resources is paramount importance and need urgent attention in India.

Maize is a high yielding crop and seems to be the most suitable commodity in the changing climatic scenario of the country. Worldwide it is the top-ranking crop utilized for food, feed and industrial raw material. India is presently producing around 28 million MT of maize which is primarily consumed as animal and poultry feed. Considering the changing socio-economic scenario, the demand for maize is poised to increase in the near future. I am pleased to learn that Maize Technologist Association of India along with ICAR-Indian Institute of Maize Research, Ludhiana and Punjab Agricultural University, Ludhiana is organizing a National Seminar on "Maize for Crop Diversification under Changing Climatic Scenario" at Ludhiana during 9-10 February, 2020. I hope that, the congregation of maize workers will deliberate to find the challenges ahead in order to enhance the maize production and productivity of the country.

I wish the event a great success.

(Parshottam Rupala)

Delhi Office : Room No. 322, 'A' Wing, Krishi Bhawan, Dr. Rajendra Prasad Road, New Delhi-110 001
Tel. : +91-11-23383975/76 **Fax** : +91-11-23383971, **E-mail** : mosrupala@gmail.com
Gujarat Office : Plot No. 219, Sector-20, Gandhinagar-382 020 **Tele.** : 079-23260013

सत्यमेव जयते
त्रिलोचन महापात्र, पीएच.डी.
सचिव, एवं महानिदेशक
TRILOCHAN MOHAPATRA, Ph.D.
SECRETARY & DIRECTOR GENERAL

भारत सरकार
कृषि अनुसंधान और शिक्षा विभाग एवं
भारतीय कृषि अनुसंधान परिषद
कृषि एवं किसान कल्याण मंत्रालय, कृषि भवन, नई दिल्ली 110 001
GOVERNMENT OF INDIA
DEPARTMENT OF AGRICULTURAL RESEARCH & EDUCATION
AND
INDIAN COUNCIL OF AGRICULTURAL RESEARCH
MINISTRY OF AGRICULTURE AND FARMERS WELFARE
KRISHI BHAVAN, NEW DELHI 110 001
Tel.: 23382629; 23386711 Fax: 91-11-23384773
E-mail: dg.icar@nic.in

MESSAGE

I am pleased to learn that Maize Technologist Association of India along with ICAR-Indian Institute of Maize Research, Ludhiana and Punjab Agricultural University, Ludhiana is organizing a National Seminar on **"Maize for Crop Diversification under Changing Climatic Scenario"** at Ludhiana during 9-10 February 2020.

Maize is a top-ranking cereal crop cultivated worldwide over diverse agro-climatic zones. India has witnessed tremendous progress in maize cultivation over the last two decades. The increasing adoption of improved hybrids, particularly single cross hybrids has encouraged farmers to bring more area under maize cultivation. Consequently, area under maize has gone up with 3 percent CAGR from 6.6 million hectares in 2000-01 to a record 9.6 million hectares in 2016-17. Presently the country is producing around 28 million MT of maize. Simultaneously the productivity has also increased up to 3.1 tons per hectare in 2017-18. However, still our maize productivity is far less than that of USA and China, the two leading maize producing countries. Although the average maize productivity of many states like coastal Andhra Pradesh, Tamil Nadu, Bihar and West Bengal is significantly high but it is not uniform throughout the country and many pockets have far less productivity. Keeping in view its diversified uses, the demand for maize is poised to increase in near future. A huge potential exists for maize export to the neighboring countries. Considering its bright future we need to redraw our strategies to identify the gaps to increase maize productivity in the low productive zones. I hope that this National Seminar will provide a much needed platform to the maize workers to address emerging issues and challenges ahead.

I extend my compliments to organizers and wish the National Seminar a grand success.

(T. MOHAPATRA)

Dated the 24th January, 2020
New Delhi

कृषि वैज्ञानिक चयन मंडल
कृषि अनुसंधान और शिक्षा विभाग
कृषि एवं किसान कल्याण मंत्रालय, भारत सरकार
कृषि अनुसंधान भवन I, पूसा, नई दिल्ली 110 012
AGRICULTURAL SCIENTISTS RECRUITMENT BOARD
DEPARTMENT OF AGRICULTURAL RESEARCH & EDUCATION
Ministry of Agriculture & Farmers' Welfare, Govt. of India
KRISHI ANUSANDHAN BHAVAN I, PUSA, NEW DELHI 110 012

प्रो. ए.के. मिश्रा
अध्यक्ष
Prof. A.K. MISRA
CHAIRMAN

Message

I am happy to know that a National Seminar on "Maize for Crop Diversification under Changing Climatic Scenario" is being organized at Ludhiana during 9-10 February, 2020, jointly by Maize Technologist Association of India, ICAR-Indian Institute of Maize Research, Ludhiana and Punjab Agricultural University, Ludhiana.

The Indian farming is going through a most critical situation in the present scenario due to the global competition of agricultural commodities. In spite of sufficient stocks of food grains, the farmer's keeps on producing wheat and rice due to assured marketing. A continuous cycle of wheat and rice cultivation in the North Western Plain Zones is stressing the natural resources of soil and water. In order to break this jinx, we need to have a high yielding, environment friendly crop. Maize suits the most due to its high yield potential and lesser irrigation requirement. Moreover, the maize grains have diversified used ranging from food, feed and as a raw material for starch and ethanol industry.

In this context, the upcoming National Seminar seems to be a righteous event, which will definitely provide a road map for maize based sustainable agricultural progress in the county. I extends my best wishes to the organizers and participating delegates for the success of this event.

(A.K. Misra)

भारतीय कृषि अनुसंधान परिषद
कृषि एवं किसान कल्याण मंत्रालय
भारत सरकार, कृषि भवन
नई दिल्ली 110001, भारत

Indian Council of Agricultural Research
Ministry of Agriculture and Farmers Welfare
Govt. of India, Krishi Bhavan
New Delhi 110001, India

डॉ. तिलक राज शर्मा
उप महानिदेशक (फसल विज्ञान)

Dr. T. R. Sharma, Ph.D
FNA, FNAAS, FNASc, JC Bose National Fellow
Deputy Director General (Crop Science)

MESSAGE

I am pleased to learn that Maize Technologist Association of India along with ICAR-Indian Institute of Maize Research, Ludhiana and Punjab Agricultural University, Ludhiana are organizing a National Seminar on “Maize for Crop Diversification under Changing Climatic Scenario” at Ludhiana during 9-10 February, 2020.

Indian agriculture is going through a difficult situation because of increased input cost compared to the farm productivity and over exploitation of natural resources of soil and water. In this context, we need to shift to a sustainable cropping systems having maximum output with minimum inputs. Maize is an important crop having highest yield potential. Within a period of 3-4 months a single kernel can produce more than 700 kernels thus proving that maize is the highest multiplier of natural energy. During the last two decades, significant improvements have been achieved in maize production across India. Consistent efforts of maize scientists have led to the enhancement of maize production from 15 MT in 2006-07 up to 28 MT in 2018-19. Recognizing the importance of maize in the present scenario, the Government of India has decided to establish the Indian Institute of Maize Research at Ludhiana. The Institute will play a pivotal role in remodelling the cropping system in the North-Western plain zone in order to have an ever green revolution in the country.

I hope the National Seminar will provide a road map for maize based sustainable agricultural progress in the country. The recommendations of the symposium will be helpful to all the stakeholders and policy makers. I extend my best wishes to the organizers and the participating delegates for success of this event.

(T. R. Sharma)

Date: 31st January' 2020
New Delhi

E-mail: ddgcs.icar@nic.in Phone: 91-11-23382545 Fax: 91-11-23097003

भारतीय कृषि अनुसंधान परिषद
कृषि अनुसंधान भवन-II
पूसा, नई दिल्ली-110012

INDIAN COUNCIL OF AGRICULTURAL RESEARCH
KRISHI ANUSANDHAN BHAWAN-II
PUSA, NEW DELHI-110 012

डॉ.आनन्द कुमार सिंह
उप महानिदेशक (बाग. विज्ञान)

Dr. Anand Kumar Singh
Deputy Director General
(Hort. Sci.)

दूरभाष सं.:91-11-25842068, **फैक्स सं.:**91-11-25841976
Ph.: 91-11-25842068(O), Fax: 91-11-25841976
email: *ddghort@gmail.com*
aksingh36@yahoo.com

Message

Corn or maize (*Zea mays* L.) is the third most important food crop at global level. In India also, strong R&D has resulted into significant improvements in maize productivity and production during the last two decades. The systematic efforts and emphasis on single cross hybrids with matching technologies on crop production and protection have led to enhancement in production and productivity maize at all India level. Further, specialty corns or maize such as, baby corn and sweet corn with short to medium duration cropping period can play important role in diversification in peri-urban and urban agricultural systems and nutrition garden. Recognizing the importance of maize in the changing climatic scenario and the significant role it may play towards crop diversification, the Indian Institute of Maize Research has taken several R&D programmes for science and technology driven support to farmers and other stakeholders. The Institute is working on various R&D aspects concerning remodeling the cropping systems to usher in an ever green revolution in the country including the North Western Plain Zones.

I am happy to know that a National Seminar on “Maize for Crop Diversification under Changing Climatic Scenario” is being organized on 9 & 10 February 2020 by Maize Technologist Association of India, ICAR-Indian Institute of Maize Research, Ludhiana in collaboration of Punjab Agricultural University, Ludhiana.

I hope the R&D issues concerning production and utilization of maize will be discussed at length in the proposed National Seminar and a road map for maize based sustainable agricultural progress in the country prepared. I congratulate the organizers and extend my best wishes for success of the event.

(Anand Kumar Singh)

कृषि वैज्ञानिक चयन मंडल
कृषि अनुसंधान और शिक्षा विभाग
कृषि एवं किसान कल्याण मंत्रालय, भारत सरकार
कृषि अनुसंधान भवन I, पूसा, नई दिल्ली 110 012
AGRICULTURAL SCIENTISTS RECRUITMENT BOARD
DEPARTMENT OF AGRICULTURAL RESEARCH & EDUCATION
Ministry of Agriculture & Farmers' Welfare, Govt. of India
KRISHI ANUSANDHAN BHAVAN I, PUSA, NEW DELHI 110 012

डॉ. पी. के. चक्रबर्ती
सदस्य (पौध विज्ञान)
Dr. P.K. Chakrabarty ARS, *FNAAS*
Member (Plant sciences)

January 31, 2020

Message

I am delighted to learn that a National Seminar on "Maize for Crop Diversification under Changing Climatic Scenario" is being organized at Ludhiana during 9-10 February, 2020, jointly by Maize Technologist Association of India, ICAR-Indian Institute of Maize Research, Ludhiana and Punjab Agricultural University, Ludhiana.

The intensive agriculture being practiced in the Indo-Gangatic plain zone to meet nutritional and food security needs has, resulted in surface and ground water depletion, soil degradation, nutrient depletion and environmental pollution. The major challenge now being faced by the government and agricultural scientists is to diversify the intensive rice cultivation. Maize based cropping system holds immense potential in this regard. Maize is a globally important crop having high yield potentials. It is very much suitable for many Indian terrains and cropping systems where it not only has potential to cut down on surface water depletion but also can enhance farm productivity and farmer's income through diversification of crops and increasing total factor productivity. State like West Bengal has lots of potential in replacing Boro rice cultivation with maize cultivation cutting down on the surface irrigation. Similarly the crop can also be grown as intercrop with winter vegetables like peas, etc. fetching farmers additional income from same land. Maize can also serve as a substitute for sugarcane in UP where it is surplus in production and thus can aid in rationing of water while increasing production of maize. States like TN which imports maize for poultry from Haryana may cultivate the crop sharing areas under cotton.

Recent report of invasive fall army worm in maize however, posed a new challenge in large scale cultivation of the crop in India. This pest along with other biotic and abiotic causes can pose serious challenge to production and needs serious interventions. I am hopeful that the deliberations to be held in the upcoming National Seminar will definitely serve to design new road map for the better future of this crop.

I wish the National Seminar a great success.

P. K. Chakrabarty

Foundation Day cum Inaugural Address

MAIZE FOR CROP DIVERSIFICATION UNDER CHANGING CLIMATE SCENARIO

Sh. Suresh Kumar, IAS (retd)
Chief Principal Secretary, Govt. of Punjab

Maize is an important food crop after wheat and rice in the world. It is not only a food crop, but also as an industrial crop, besides its use for feed and fodder purposes. Globally, maize is cultivated in 170 countries on over 185 million hectares with a productivity of 5.62 t/ha. USA and China contribute around 35 and 21 per cent of total global production, respectively. India ranks fourth in area and sixth in the production.

The importance of maize in Asia's cropping systems has grown rapidly in recent years, with several countries showing impressive growth in its production and productivity. There is scope for further expansion of maize area in the region with innovations in crop improvement, management and diversification. International and national institutions engaged in maize research and developments are also emphasizing technology targeting and partnerships involving all stakeholders through capacity development to effectively up-scale innovations for greater impact. Some of the innovations like single cross maize hybrids, quality protein maize (QPM), genetically modified (GM) maize, conservation agriculture (CA), small farm mechanization, transplanted maize, technologies for winter and spring maize, baby corn, sweet corn, biofuel production, etc. offer exciting opportunities for future growth and development of maize in the region.

Maize production has shown a tremendous growth in the country, which was possible mostly due to area expansion and adoption of improved production technologies. It is mainly used as food, feed, fodder and also has huge application as industrial raw material. Current production of maize in India is around 28 million MTs, of which roughly 62% is used as feed, 18% for industrial purposes, around 10% for export, 6% as food and 4% for other purposes including seed. The increased production has been achieved due to increasing demand particularly in feed industry. Presently, around 15 MMTs of maize is used as animal feed and country's demand for this would be about 32 MMTs by 2025. Indian starch industry is growing rapidly which would require 15 MMTs by 2025 from the present level of 4.25 MMTs. From a net importer of maize till late 1980s, India has emerged as maize grain exporter and would have the opportunity to export about 10 MMTs of maize by 2025.

Punjab played a key role in making the country self-reliant in food production through Green Revolution. Hard working, dynamic and resilient farmers of the state have transformed the nation from a 'food deficit' to 'food surplus' country. However, the extensive cultivation of high yielding wheat and rice has caused overexploitation of the precious natural resources namely water and soil. To address this, the state needs to diversify from rice cultivation to other high yielding *kharif crops*. Maize is the most suitable alternative and there is a need to rework government's strategies and programs to achieve significant enhancement in maize cultivation in the state.

The impact of climate change on agricultural production is the most prominent in the tropics and subtropics. South Asia is particularly vulnerable for multiple stresses due to tropical climatic conditions. India is also facing extreme weather events like flooding, high temperature, drought, reduction in wet days, and reduction in sunshine etc. due to accelerated climate change.

Kharif maize dominates the maize scenario, where more than 80% of the area is rainfed, which is the main reason for lower maize productivity in India. Drought is observed is a major constraint across the rainfed environments. Directly and indirectly cereal crops, viz., wheat, rice and maize account for approximately 50% of human food calories. Among these top cereals, water requirement of maize is the lowest (500 mm) as compared to that of rice (2100 mm) and wheat (650 mm). Further, cultivation of rice during *kharif* season over a period of 5 decades has led to one of the major serious concerns of lowering ground water table in Punjab. Punjab is thus facing the challenge of long-term sustainability of agriculture, which can be addressed through diversification of the rice with maize. Being a less water-demanding crop, shifting from rice to maize could immediately address the issue of declining water table.

Burning of rice-straw is another major issue particularly in Punjab and the nation as a whole due to the very short window available between harvesting of rice and sowing of wheat. It can be addressed by shifting from rice to maize cultivation. The productivity of maize in *kharif-dominated states* like in Rajasthan (1.6 t/ha) and Gujarat (1.6 t/ha) is quite low. Cultivation of composites and local landraces in these regions is one of the main reasons of such lower yield. Yield capacity of single cross hybrids (SCH) is much higher than composites, synthetics and OPVs. Thus, more and more farmers' fields should be covered under SCH to get a handsome return. Again, seed companies including public and private sector produce only 50-60 thousand tonnes of single cross hybrids (SCH) seed, which can cover about 25-30% of acreage under maize. Timely availability of improved seed is still an issue. Adoption of improved cultivation practices needs to be up-scaled. Thus timely availability of hybrid seeds of high yielding varieties to the farmers has to be ensured to achieve maize as a credible option to replace rice cultivation.

With climate changes, diseases like PFSR and BLSB and insect-pests like stem borer are becoming more serious. A new invasive pest, fall armyworm is posing new threat to the food security of the country. Therefore, development of high yielding climate resilient hybrids with in-built resistance and tolerance to diseases, pests and various abiotic stresses and adaption of such varieties by farmers are required.

Maize is used worldwide for bioethanol production. In India, we are importing crude oil to meet our energy demand. Ethanol is not only a greener form of energy but also lets India to reduce its energy imports. In the year 2018-19, requirement of ethanol was 511 crore litres but the availability was about 30% of the total demand. This can attain blending target of 5.5%, whereas it is fixed at 20% by 2020. This further highlights that in the coming years, the demand for ethanol and consequently for maize, is going to rise exponentially. We should thus focus on producing more ethanol as it will help to cut imports, increase farmers' income and promote local industry.

Cultivation of maize can address a number of other issues to promote ecological balance and environmental sustainability. Maize based conservation agriculture can help in maintaining the soil fertility and soil ecosystem. The adoption of zero tillage resource conservation in maize cultivation will help to improve environmental quality by reducing the emission of greenhouse gases. Maize cultivation will also enable the farmers to achieve reduced cost of electricity on water pumping, reduced risk of terminal heat stress in wheat due to advanced planting, reduced groundwater pollution because of less use of pesticide in maize production etc. The required technologies like suitable high-yielding single cross hybrid maize cultivars, efficient weed management system, machineries for mechanized cultivation of maize and conservation agriculture practices are available to promote maize as an alternative crop for crop diversification. For this, our agriculture scientists and researchers and more importantly ICAR-Indian Institute of Maize Research, Ludhiana deserve appreciation for their commendable work.

To mitigate the serious effects of climate change, systematic and stepwise strategy involving research and policy changes is required, so that future demand of maize for food, feed, fodder, and raw materials for industries is fulfilled. The most climate change vulnerable pockets of the country where water scarcity is likely to be a problem in the near future need to be identified using the most advanced information system at district and sub-district levels so that the high yielding drought tolerant single cross hybrid technology recommended for a particular area could be used to replace the more water consuming crops like rice. Often there is a yield gap in the potential and actual yield of maize in farmers field, which hinders in wider adoption by the farmers. It is some time attributed to low plant population in farmers field, thus designing new plant architecture for high density planting is an obvious breeding target to break the maize productivity plateau. The end product of maize is hybrids which is a product of a cross between two inbred lines, therefore development of suitable inbred lines in the shortest period of time using accelerated breeding approach like doubled haploid (DH) technology can help to accelerate the maize yield than that of other crops in no time and ensure high remuneration to maize farmers. As the demand for ethanol is going to increase, focused research on newer methods for production of ethanol more efficiently and identification of maize hybrids more prone to ethanol production is also required.

Appropriate policy and programme interventions from the government can definitely make an impact in favour of crop diversification through maize. One of the major stimuli to farmers is assured market through government procurement of maize at minimum support price (MSP) as in the case of rice and wheat. Development of proper infrastructure is another aspect, which can promote maize diversification particularly for specialty corns like sweet corn, baby corn and popcorn as the demand for these is increasing day by day in the country. The silage prepared from maize of best quality is highly preferred over silage of other crops. Hence, the cultivation of fodder and silage maize is another avenue to bring crop diversification. Establishment of linkages between the specialty corn (baby corn and sweet corn), fodder and silage cultivation farms and dairy farms could further boost livestock industry and will also ensure better remuneration to maize farmers.

One of the major drawbacks of maize cultivation is lesser mechanization of maize farming as compared to rice and wheat. Promotion of mechanized maize cultivation through arrangement of machines like combine harvester, dehusker, maize sheller and maize grain dryers etc. to the farmers on custom-hire basis, will help to achieve the goal. Establishment of end-user industries like food, feed and starch industries and storage facilities would promote entrepreneurship and attract investment in agriculture and create competition in the market. Deficiency price support, differential interest rates for cheaper credit and competitive crop insurance schemes that will help in encouraging maize cultivation over other crops, need to be introduced to ensure adequate margins and incomes to the maize farmers. And if the government wakes up to these realities of farming as a main source of livelihood for the majority of our population, the country can perhaps achieve the target of raising farmers' income and reducing the stress natural resources much faster.

Lead Lectures

MAIZE FOR SUSTAINABLE AGRICULTURE IN CHANGING CLIMATE

Baldev S. Dhillon[1], Surinder K. Sandhu[2] and J.S. Chawla[3]
[1]Vice Chancellor, Punjab Agricultural University, Ludhiana
[2]Principal Maize Breeder, Punjab Agricultural University, Ludhiana
[3]Incharge, Maize Section, Punjab Agricultural University, Ludhiana

Climate change and its affect on agricultural production are intertwined. Temperature and moisture extremes, unseasonal rainfall, droughts, floods, cloud bursts and cyclonic storms etc. are becoming more frequent. The impacts of climate volatility on our cropland area; cropping systems and their productivity; on severity and alteration of biotic and abiotic stresses, have emerged as serious challenges for scientific community and policy makers. The ost recent example of the threats due to climate change and volatility is the spread of desert locust, *Schistocerca gregaria*, in western parts of India in winters of 2019-20. The locust attack in India used to subside by mid-November but it has persisted in winter months due to favourable weather for its breeding. The prolonged monsoon and development of unusual weather disturbances in the form of continuous cyclonic winds over parts of Rajasthan and Punjab may be the possible reasons (Locust Warning Organization, personal comm.). As per Dr. Mohammad Ashraf, Vice Chancellor, University of Agriculture, Faisalabad, the current locust outbreak of locust in Pakistan was unanticipatedand was initially expected to subside by mid-November. However, the outbreak has persisted due to climate change-induced favourable weather conditions allowing the locust to breed.

There are many other examples of changes in incidence and severity of pests. One of these is the deadly polyphagous pest fall armyworm (FAW), *Spodoptera frugiperda*, with a strong preference for maize. It is native to tropical and subtropical regions of the America and has invaded maize in India, as recently as May 2018. Since its first report from Karnataka, it has spread to almost all the states (except Himalayan region).

Pink stem borer, *Sesamia inferens,* a key insect pest of paddy, was earlier restricted to the peninsular India. Its incidence was reported in other crops also. In Punjab, it used to appear in paddy but not in wheat, till recently. Both pink stem borer and army worm have infested early sown wheat in Punjab in November-December 2019 and 2020. Though, the changing cropping system, i.e. predominance of paddy-wheat crop rotation, may have hastened the incidence of some pests, yet the major factor underlying the new threats is climate change-aided biological and ecological adaptation of the pests to the conditions in new areas. In this scenario, we need to shift our agriculture towards more resilience and sustainability to ensure national food and nutritional security and farmers' livelihood. Maize can play an important role in this.

Maize (*Zea mays* L.), the queen of cereals, surpasses all other cereals and food crops in its ability to adapt to diverse agro-ecological niches and being cultivated from 58^{o}N to 55^{o}S latitude. In India, it is traditionally a *kharif* season crop, but it is now cultivated in spring season too. The expansion started in 1960s or may be 50s, first to *rabi* and then to spring season. Further, maize, being a C_4 plant, is physiologically highly efficient. The demand for maize is expected to increase in coming years, the major drivers for which in India include demand for feed for expanding livestock and poultry sector and fodder; processed foods like corn flakes, bakery products, fine cereals and maize-based concentrates due to changing lifestyle;

and raw material for expanding industrial sector (starch, ethanol, rubber, paper, cosmetics, pharmaceuticals etc.).

In India, maize is the third most important cereal crop after rice and wheatand accounts for around 10 per cent of total food grain production in the country. It was grown over an area of about 9.38 million ha, contributing 28.7 million t in 2017-18 and engaging about 15 million farmers. The national productivity was 3.06 t/ha. In Punjab, it was grown on 386 thousand ha during 1965-66 and had peak acreage of 577 thousand ha during 1975-76. In 2017-18, it was cultivated on 114 thousand ha and had a productivity of 3.71 t/ha. The productivity at the national level and that of state is lower than of many countries, even after duly considering the different agro-ecologies, which underlines the need to reorient our research strategies.

In Punjab, the area under paddy cultivation has continuously increased since green revolution (293 thousand ha in 1960-61 to 3.10 million ha in 2018-19). Besides improved technologies, Government policies (assured minimum support price and procurement, provision of subsidy on inputs etc.) aimed at National food security have contributed to this expansion. This has reduced on-farm diversity which is a must to provide resilience under climate change. The paddy dominant agriculture is also disinheriting the state of its groundwater resources. Besides this loss, the lowering groundwater table necessitates the farmers to spend more funds for installation and operation of deeper tubewells. With a little in-house demand in the state, >85% of paddy produce is moving out of state, leading to severe soil nutrient mining and deterioration in soil health. There is environmental pollution due to mismanagement of paddy straw. With surplus availability of food grains, there is likelihood of diminishing demand of paddy from Punjab.

Diversification of agriculture provides a solution to most of these concerns. *Kharif* maize, with less water requirement than paddy, has been recognized as one of the feasible alternatives to replace predominant wheat-paddy with maize-paddy cropping cycle. Besides water saving, maize-wheat cropping system gives about 10% higher wheat productivity than paddy-wheat rotation. But poor competitiveness of maize vs. paddy due to lower and unstable yields, demand and market price, paddy cultivation oriented infrastructure, mechanization, markets and processing are major issues facing a large scale cultivation of maize.

As the nation move towards doubling the farmer's income by 2022 and to achieve maize production target of about 50-60 million tonnes by 2030, there is a clarion call to devise research strategies to design maize for higher production and sustainable agriculture. In today's era, new sciences of genomics, proteomicsand precision agriculture provide an unprecedented opportunity to harness the full genetic potential of maize plant. Some of the important research and development strategies are discussed below. However, better predictions of future climatic patterns and understanding of the biological responses to the same will be a key issue in realisation of the fruits of our research and development efforts.

Maize grain productivity

Undoubtedly, we have made significant progress in enhancing productivity which rose from 1 to 3 t/ha during 1965-66 to 2017-18 at the national level. To further enhance productivity, however, some traits need to be given greater emphasis. Development of longer maturity duration hybrids than those presently availableand incorporation of temperate germplasm from US and other regions having high genetic potential and rapid grain filling, needs to be emphasized. Development of hybrids well adapted to high-density planting is a key area. In this venture, narrow erect leaves, sparse tassel branching, shorter anthesis-silking interval and prolificacy are important traits. With combine harvesting, lodging resistance has gained importance for which strong root system and stem, medium ear placement and stay green traits are needed. The long duration hybrids should also have rapid dry down of ears/grains.

Maize as green fodder and silage crop

Maize is an important green as well as dry fodder as digestibility of its fodder is better than sorghum, *bajra* and other non-forage crops. Maize does not have any anti-quality factor unlike some other fodder crops. But maize has not got required attention on this front. PAU bred J1006, a fodder purpose variety released in 1989, is a ruling variety even today along with an introduction, African Tall. To breed fodder maize, high biomass, fast growth, prolificacy and digestibility are most important traits. For increasing biomass, tall landraces need to be funnelled in.

Maize is also preferred for silage making over other fodders as maize plant is easy to chaff, requires less labourand its silage is soft. In an evaluation by the National Dairy Development Board (NDDB) of PAU-bred hybrids, PMH-1 was reported as very good for silage making. Development of dual-purpose maize varieties is a good potential area. In dual purpose varieties, stay green is also an important trait. For fodder maize research, the collaboration among Indian Maize Research Institute (IIMR)-AICRP, Indian Grassland and Fodder Research Instituteand NDDB (in Punjab between PAU and Guru Angad Dev Veterinary and Animal Sciences University) needs to be strengthened. Focusing on maize breeding for fodder is very important for the promotion of dairy industry which is essentially required for diversification of agriculture.

Biofortified maize

With nation not only having achieved food security but overflowing foodgrains in godowns, it is high time to focus on nutritional security. Development of high yielding, high lysine and tryptophan maize, commonly known as Quality Protein Maize (QPM) and biofortified maize enriched in provitamin A holds significant promise. The nutrient-rich maize grains should be used make functional foods and value-added items as the demand of such nutraceutical products is increasing with improving living standards, increasing health awareness and urbanization. Niches/hubs will need to be created particularly in urban and peri-urban areas. Further, the high carotene content of yellow grained maize feed is considered useful towards imparting yellow colour to egg yolk thereby enhancing its importance in poultry industry. However, cultivation of nutrient-rich maize would be possible only if these are made agronomically viable.

Speciality maize

There is a good possibility diversifying maize cultivation by promoting speciality maize types, namely baby corn, pop corn, sweet corn and waxy corn. These are high value crops and therefore helpful in increasing farm income. Baby corn and sweet corn also provide green fodder after the harvest of the ears. In baby corn, prolificacy and male sterility are important traits. In pop corn, popping ratio is 20-25:1 which needs to be upgraded. Waxy maize having nearly 100% amylopectin compared to 75% amylopectin and 25% amylase in normal maize kernels, is gaining popularity as instant energy source. There is a significant export market for waxy maize in Europe and Asia.

Major constraint in the commercial cultivation of speciality maize types, like that in biofortified, is their poor agronomic performance as compared to normal corn. Thus, research efforts need to be strengthened for which resources need to be generated through Research-Industry interface. In addition, infrastructure facilities like small scale processing units, cold chains, storage facilities and strong linkage of farmers and industry are need to be addressed.

Tolerance to abiotic stresses

Abiotic stresses like water logging, drought and heat cause significant yield losses in maize. Water logging stress is one of the major limiting factors in its productivity in tropical and subtropical regions and its importance has increased with changing rainfall pattern characterized by erratic, heavy rains. Continued rains during flowering cause pollen washand rains accompanied with wind storms lead to lodging of the crop. A secondary effect of water logging is a deficit of essential macronutrients like N, Pand K. Fifteen percent of all maize growing areas of South-East Asia face water logging problem, which may lead to yield loss in the range of about 25–30% annually. It may be noted that erratic, heavy rains cause much less damage to paddy crop and thus, these are hindering crop diversification.

Drought is another serious stress. It affects all stages of plant growth but pre-anthesis and grain-filling periods are more sensitive, resulting in a significant reduction in grain yield. The delay in silking increases anthesis-silking interval and decreases male–female flowering synchrony resulting in poor seed set and yield. Heat stress, which generally accompanies drought, leads to top-firing, tassel blast, killing of pollen, drying of silk and hence, poor seed set and yield.

Increasing global temperature and frequency of erratic rainfall necessitates the need to strengthen research on tolerance to drought/heat and water logging stresses in maize. CIMMYT germplasm having drought and heat tolerance may be extensively evaluated in our environments. For water logging tolerance research on root traits must be strengthened. Genomic regions identified for water logging tolerance can be helpful in marker assisted breeding for incorporating flood tolerance in high yielding cultivars. Further, other mitigation strategies need to be devised to meet the challenges of these stresses.

Tolerance to biotic stresses

A number of diseases and insect-pests affect maize crop at different growth stages across the seasonsand biotic stress pattern is getting affected by climate change (some examples mentioned earlier). Maize stem borer, *Chilo partellus*, is already a serious pest and now FAW has emerged as a very serious one. The increased incidence of banded leaf and sheath blight caused by *Rhizoctonia solani*, also needs an urgent attention. Its wide host range and non-availability of resistant donors further aggravate the situation.

Quarantine measures are the first line of defence in plant protection and should be strictly followed. The experience with FAW has again brought its importance in focus. Further, strengthening research on the development of seed capsule having in-built resistance/tolerance to biotic/abiotic stresses is need of the hour. Our research efforts on disease resistance have been generally successful. But, those for insect pest resistant do not lead to expected progress. Long and consistent breeding efforts in maize stem borer could improve genetic resistance only to a very moderate level. It should be a matter of great concern. Apparently we need to concentrate on evaluation of larger set germplasm and allele mining thereinand application of other molecular technologiesand if need be, to make use of transgenic approach. This is also true to some extent for abiotic stresses. Development of IPM modules, using sustainable pest control measures and validation of IPM modules at farmers' fields is ultimately the key challenge to maize researchers.

Development of medium capacity fast drying maize dryers

Combine harvested maize produce, having >25% moisture content, faces major marketing issues and is generally sold by farmers at low price. Farmers can not delay the harvesting until moisture content attains an acceptable level for safe storage, because wheat crop is to be sown after maize. This problem may aggravate with the cultivation of long duration hybrids which must be developed to compete with paddy crop. A portable maize dryer of 3 ton capacity has been developed by PAU to dry maize grains. The grains with a moisture content of 25% can be reduced to 15% in 6-8 hours using this dryer, but the experience so far indicates that its capacity is not enough. On the other hand, large capacity imported drier installed at some maize markets have also not proved to be of great utility. Thus, there is a need to develop medium capacity, fast drying (as viability is not an issue unless seed is being dried) dryers and to make them available to farmers on cooperative basis.

Agronomic interventions to reduce yield gaps

National maize productivity is 3.06 t/ha whereas experimental yields of improved hybrids hover around 6.5-7.5 t/ha. To make maize a commercially viable crop, this wide gap needs to be plugged in through large scale front line demonstrations of the high yielding varieties, along with the improved production and protection technologies particularly during *Kharif* season. Some of the factors which need to be emphasized are the cultivation of varieties adapted to the given agro-ecology (e.g. single cross hybrids in ecologies having favourable environment), use of good quality seed, precision sowing, weed controland taking care of the crop facing biotic/abiotic stress. This should get priority as these efforts will have immediate impact.

New breeding methods and approaches

Breeding methods namely modified S1 recurrent selection, recurrent selfed-plant mass selection and comprehensive recurrent selection have higher genetic gain per year compared to population improvement methods available earlier. These may be applied for the improvement of populations and development of base germplasm to be used to derive inbred lines.

Rapid progress has been made in the developed world for development of inbred lines through doubled haploid (DH) technology using haploid inducer stocks. This approach shortens the time span required for the line development by 3-4 generations. However, the haploid inducer stocks have poor adaptation to tropical climate. Second generation tropicalized haploid inducer stocks developed by CIMMYT need to be used with vigour and must be improved for adaptation to our agro-ecologies. ICAR has developed winter nursery facility for taking an off-season crop. But many breeding programmes in the developed world are raising three crops per year. IIMR-AICRP should consider developing of a similar facility to speed up inbred line development and undertaking other breeding activities.

Molecular breeding and exploring wild resources

Major advances are being made in molecular breeding, genomics, gene mining, editingand transgenics. Good work is going on in genomics and molecular markers are being routinely applied in some crops in our country. The efforts on the identification of desirable genes/ QTLs and their funnelling into maize gene pool must be expanded. The decision on transgenics need to be taken on case-to-case basis rationally considering the source of transgene (animal or plant kingdom), its expression (whether it produces toxin or not), trait under investigation (resistance to biotic or abiotic stress, chemical composition or agronomic trait), effect on micro and macro environment etc. Needless to mention, biosafety regulations must be ensured, all aspects must be evaluated thoroughly and considered seriously but there should not be generalized skepticism regarding biosafety.

The availability of new molecular tools has potential to accelerate introgression breeding and have enhanced interest in the identification and exploitation of desirable genes in landraces and wild relatives. The research at Indian Agriculture Research Institute, New Delhi has rekindled the hope of exploiting the useful variability in Sikkim Primitive race of maize known since long to have gene(s) for prolificacy. Teosintes are a valuable source for broadening and enriching the maize gene pool. Given the close genetic relationship between maize and teosinte (*Zea mays* ssp. *mexicana*), research for the transfer of resistance to leaf and sheath blight is underway at PAU. Besides, teosinte is an excellent source for enhancing fodder production potential of maize. Backcross derivatives from *Z. mays* × *Z. mays* ssp. *mexicana* crosses have shown useful variation for maize stem borer resistance. This subspecies also seem to survive drought through escape mechanism owing to very short vegetative growth period and probably has drought resistance genes. Other teosintes, namely *Zea perennis* and *Zea diploperennis* showed resistance to biotic stresses and *Zea luxurians* and *Zea nicaraguensis* are adapted to frequent rainfalls and possess unique flooding resistance traits.

Seed production and public private partnership

It is agreed that use of quality seeds of appropriate variety alone can significantly increase crop yields. To facilitate good quality seed production, we must develop vigorous, high yielding inbred lines, seed parent with large number of bold grains and pollen parent be a profuse pollen producer. Further, public sector research institutions neither have resources for large scale hybrid seed production nor it is their mandate. Thus, a strong public-private partnership is needed for this extremely important task.

Strengthening All-India Maize Improvement Project

Maize has the credit of being the crop in which All-India Crop Improvement Project, now generally known as AICRP, launched in 1957, gave outstanding performance. The AICRPs are now operating across disciplines and serving as backbone of the National Agricultural Research System. These are characterized by sharing of ideas and inputs/germplasm by multi-disciplinary, multi-location teams to develop products and technologies and evaluate the same for their wide and specific adaption/application in shortest possible time. These projects need to be strengthened (in maize to the level of paddy, if we want to compete with paddy) as their relevance has increased in today's scenario of climate volatility, frequent abiotic stresses and sudden outbreaks of diseases and insect-pests. Further the AICRP on maize may consider reorganizing to focus on exploitation of temperate germplasm in temperate and especially in subtropical regions of India.

INCREASING MAIZE PRODUCTIVITY, CLIMATE RESILIENCE AND NUTRITIONAL QUALITY IN THE TROPICS – CHALLENGES AND OPPORTUNITIES

B.M. Prasanna
Director, Global Maize Program, CIMMYT (International Maize and Wheat Improvement Center) & CGIAR Research Program MAIZE
b.m.prasanna@cgiar.org

1. Introduction

Achieving sustainable food and nutritional security, i.e., the basic right of the people to produce and/or purchase the nutritionally balanced food they need, without harming the social and biophysical environment, has to be the funademental goal of any nation. Over the last seven decades, India made immense progress towards food security of the population. Since 1950, the population almost tripled, but food grain production had more than quadrupled. India is now among the largest producers of rice, wheat, pulses, fruits, vegetables, milk, cotton, horticultural crops, dairy and poultry, aquacultureand spices. Agricultural production in India is valued at US$ 401 billion in 2017, which is more than that of the USA (US$ 279 billion). India's global trade in agricultural produces also fetches higher revenue for the country than the services and the manufacturing sectors, ranked 11th and 12th, respectively (Singh, 2019). The growth in Indian agriculture over the last 16 years was 350 per cent higher than the one achieved in the erstwhile period of 30 years (Shroff, 2019).

Despite this impressive progress, there is no scope for complacency. It is estimated that by 2030, Indian population would be 1.52 billion; by 2050, it would be approximately 1.7 billion, which will be the highest in the world and about 400 million more than China, the most populous nation today (Singh, 2019). By 2050, India needs to step up production of all agricultural commodities by around 30 per cent in food grains and to more than 300 percent in vegetable oils to meet the needs of increased population and rising living standards (Singh, 2019). Also, by 2050, to meet the diverse demands of the population, it has been estimated that land productivity has to be increased by 4 times, water productivity by 3 timesand labour productivity by 6 times (Chand, 2012). All this has to be achieved with lesser natural resources, low carbon emission technologiesand without major environmental and ecological footprints.

2. Building Resilience in Farming Communities to Climate-induced Risks

The negative impacts of frequently occuring climatic extremes/variabilities on agricultural production are most often felt by the resource-constrained smallholders in the tropics, be it in Africa, Asia or Latin America. Abiotic stresses, especially drought, heat, flooding/waterlogging, soil acidityand combinations of various abiotic stresses have a huge negative impact on the rainfed crop yields. For instance, in South and South East Asia, more than 80 percent of the maize-growing area is rainfed and prone to various climatic extremes/variabilities. While we tend to focus mostly on abiotic stresses in the context of climate change, it is equally important to consider the changing spectrum of pathogens and insect-pests due to increase in temperatures. In the future, pest species are likely to differ in their responses to global warming, with changes in their relative impacts both geographically and among various crops. Deutsch et al. (2018) highlighted that global yield losses of three of the most important cereal staples – rice, maize and wheat – are projected to increase by 10 to

25% per degree of global mean surface warming. Crop losses will be most acute in areas where increase in temperatures may lead to increases in both population growth and metabolic rates of insects.

Building climate resilience in the smallholder farming systems requires implementation of an intenisve multi-disciplinary and multi-institutional strategy. This should include extensive awareness creation and widespread adoption of climate-resilient crop varieties and climate-smart agronomic management practices, strengthening of local capacitiesand much stronger focus on sustainability. An array of agricultural production technologies and practices, including stress-tolerant improved crop varieties, conservation agriculture practicesand agroforestry systems, that aim to mitigate climate-induced risks and foster resilience have been developed through national and international AR4D initiatives over the past two decades. In addition, institutional interventions (e.g., index-based agricultural insurance) that seek to mitigate risk and build resilience through other mechanisms could play a complementary role to climate-smart agricultural production technologies/practices (Hansen et al., 2019).

CIMMYT and partners in Africa, Latin America and Asia are intensively engaged in developing and deploying climate-resilient improved varieties adapted to the tropics (Cairns and Prasanna, 2018). CIMMYT has used two major approaches for developing sources of abiotic stress tolerance that have been widely used in maize breeding programs in SSA, Asia and Latin America. The first was constitution of drought-tolerant populations for undertaking recurrent selections and derivation of elite inbred lines. The DTP-Y, DTP-Wand La Posta Sequia are examples of such populations. The second approach was full-sib recurrent selection under managed drought stress within elite populations to increase the frequency of drought tolerance alleles in germplasm already adapted to the lowland tropics (e.g., Edmeades et al., 1999). Both approaches have generated several inbred lines that have become important sources of drought and heat tolerance in maize (Cairns et al., 2012). Thus, population formation and improvement have resulted in an increase in the frequency of drought-adaptive alleles and identification of superior sources of drought tolerance (Edmeades et al., 2017).

An array of elite maize varieties with drought tolerance (**Figure 1**), disease resistance and other farmer-preferred traits have been developed by CIMMYT and deployed by seed companies across sub-Saharan Africa (SSA). Between 2007 and 2018, CIMMYT and partners in SSA released more than 250 climate-resilient maize varieties in 13 African countries. In 2019, more than 85,000 tons of certified seed of DTMA/STMA-derived multiple stress-tolerant maize varieties were produced and commercialized by over 100 small- and medium-enterprise seed company partners across SSA, covering an estimated 3.3 million hectaresand benefiting about 5.5 million farm households or over 33 million people (Cairns and Prasanna, 2018). Asia needs to emulate this success story from Africa in terms of extensive deployment of climate-resilient crop varieties through intensive and focused initiatives and strong public-private partnerships.

Through the USAID-funded Heat Tolerant Maize for Asia (HTMA) project, a large heat-stress phenotyping network, comprising 23 sites in four Asian countries (India, Bangladesh, Nepal and Pakistan) has been established. Several CIMMYT-derived drought-tolerant and heat-tolerant CIMMYT-derived elite maize varieties have been released during 2016-2018 through public and private sector partners in South Asiaand several more are in pipeline. Tesfaye et al. (2017, 2018) highlighted the potential benefits of incorporating drought, heat and combined drought and heat tolerance into improved maize varieties in the climate-vulnerable tropical environments.

Figure 1. CIMMYT-derived drought-tolerant maize hybrid (right) versus drought-susceptible commercial check (left) under managed drought stress phenotyping at Kiboko, Kenya.

For new climate-resilient crop varieties to contribute towards smallholders' adaptation to climate variability, it is important to further strengthen the formal and informal seed systems. Delivering low-cost improved seed to smallholder farmers with limited purchasing capacity and market access requires stronger public-private partnershipsand enhanced support to the committed local seed companies, especially in terms of information on access to new products, adequate and reliable supplies of early-generation (breeder and foundation) seedand training on quality seed production, quality assurance/quality control (QA/QC)and seed business management. While enhanced adoption of climate-resilient crop varieties is undoubtedly important, one must not ignore the need for complementary uptake of other climate-smart, sustainable intensification practices. Intensive and deliberate efforts are needed to provide smallholder farmers with usable climate risk information and skills to build their comprehensive adaptive capacity.

3. Increasing Genetic Gain for Climate Resilient Traits

"Genetic gain" in simple terms refers to the gain in population mean achieved through each breeding cycle. Breeding being a cyclical process of crossing, evaluating, selecting and crossing again, the efficiency (both in terms of time and cost) with which breeding programs can make considerable shift in population mean from one cycle to the other determines the extent of genetic gains. Regardless of the trait of interest, or the breeding methods employed, genetic gain represented by "ΔG" serves as a simple universal expression for expected genetic improvement (Falconer and Mackay, 1996).

Increasing genetic gain in maize grain yield in the stress-prone environments of the tropics is indeed a challenge, but possible nevertheless with a clear product development and deployment strategy (Cairns and Prasanna, 2018). Conventional maize breeding, although successful, is a relatively slow and resource-intensive process. The increasing demand for high-yielding, multiple stress tolerant and nutritionally enriched maize varieties warrants accelerated breeding that makes use of modern tools and technologies, including doubled haploids, molecular markers, high-throughput and reliable phenotyping, off-season nurseries and decision support tools. The "breeder's equation" provides the focus around which new technologies can contribute to increased genetic gains (**Figure 2**).

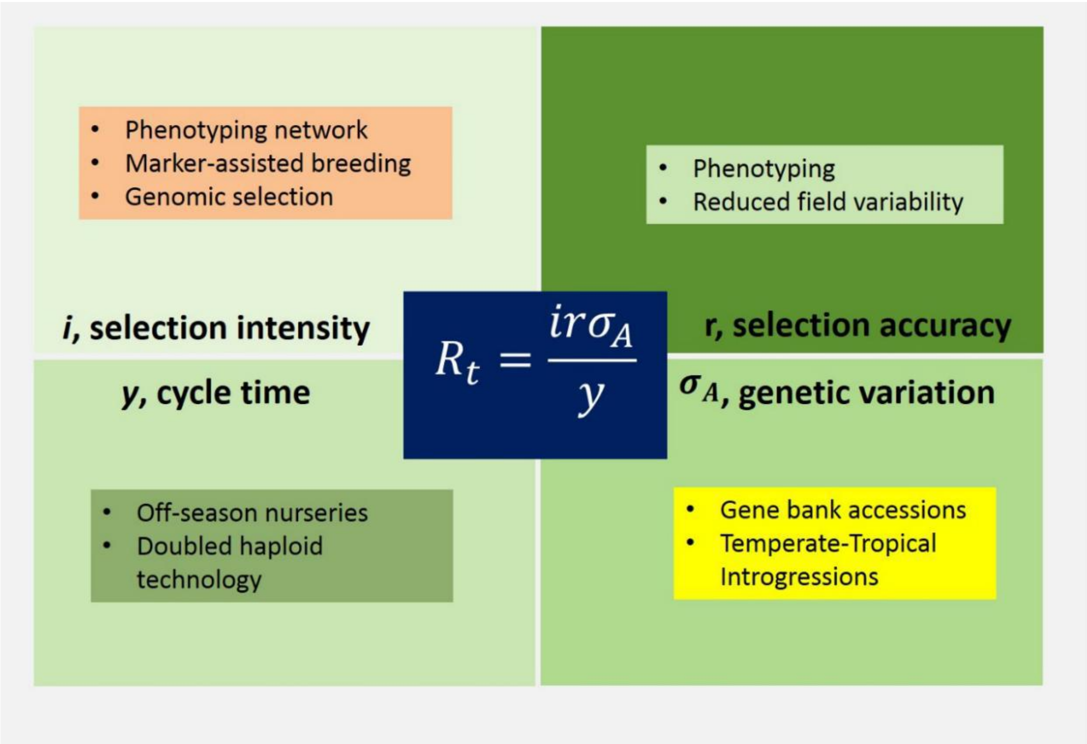


Figure 2. Some of the key components for increasing genetic gains for maize yields in the stress-prone environments of the tropics.

3.1. Genomic-assisted Breeding for Increasing Genetic Gain and Accelerating Improved Varietal Development

Diverse conventional breeding methods have been applied over the decades (and continue to be used) by breeding institutions, including intra- and interpopulation improvement schemes, inbreeding and hybridization, backcrossingand the use of selection indices. With the aim to increase genetic gains and accelerate product development, molecular markers are now being increasingly used by crop breeding programs globally. At CIMMYT, molecular markers are being used at various stages of the maize breeding process, including germplasm characterization, mapping of genes/QTL that control important traits, population improvement through marker-assisted recurrent selection, genomic selection for improving complex traits, Quality Assessment/Quality Control (QA/QC) etc. Genomic interventions could begin at the pre-breeding stage by tapping into the extensive genetic variations that exist within landraces and exotic germplasm; the "Seeds of Discovery" project that involves intensive characterization of a wide array of maize landracesand developing a "Maize Molecular Atlas" is an important example (https://seedsofdiscovery.org/maize/maize-molecular-atlas/).

CIMMYT maize breeding teams in Africa, Asia and Latin America use an array of modern tools/technologies for accelerating improved varietal development and for increasing genetic gain for grain yield in stress-prone environments of the tropics (Cairns and Prasanna, 2018). These tools include the doubled haploid (DH) technology (Prasanna et al., 2012; Chaikam et al., 2019), low-cost and high-throughput phenotyping using proximal and remote sensors (Makanza et al., 2018a,b), genomics-assisted breeding (Nair et al. 2018)and breeding information management system, including decision-making tools. With the rapid reduction in genotyping costs, new genomic selection technologies have become available in several crops that allow the crop breeding cycle to be greatly reduced, facilitating inclusion of information on genetic effects for multiple stresses in selection decisions (Xu et al., 2017).

Molecular technologies offer the ability to expand the size of a breeding program, thereby increasing selection intensity, without increasing phenotyping requirements. Genotypic information can be used to select germplasm prior to the phenotyping stages and the capability to increase this phenotypically untested layer will allow the total number of genotypes within a breeding program to be expanded (Cooper et al., 2014). When carefully implemented, molecular strategies can also reduce cycle time by two to three years (Gilliham et al. 2017).

Within the CGIAR Research Program (CRP) on Maize (abbreviated as "MAIZE"), three strategies are currently in use: forward breeding (FB), marker-assisted backcrossing (MABC)and genomic selection (GS).

- FB is a simple form of population enrichment using markers tightly linked to genomic regions of high importance. FB is typically used to enrich breeding populations for favourable alleles of large effect genes or QTL influencing resistance to important diseases or contributing to nutritional quality.
- MABC is used to introgress markers closely linked to major genes or a few loci from a donor parent (DP) to a recipient parent (RP), producing higher quality and improved versions of recipient lines in less time than conventional backcrossing using phenotype alone. Using tightly linked flanking markers, a target gene can be transferred with minimum linkage drag in two to three backcross generations.
- GS, a widely adopted technology in advanced crop breeding organizations, uses genome-wide sequence information to estimate all marker effects and to select for individuals with high genetic estimated breeding values (GEBVs). GS effectiveness is a product of the quality of the training population with both genotypic and phenotypic data used to estimate the marker effects in the predicted population. GS is especially useful for improving complex traits.

3.1.1. Forward breeding: Over the past 25 years there has been extensive research into understanding the genetic basis of grain yield under different environments (e.g., Xu et al. 2017); yet, majority of these studies remain in the literature, unrealised within breeding programs (Bernardo, 2016). In the last decade, deployment of molecular markers has increased significantly in the public sector for identification of genes/QTL associated with important traits. Within the CIMMYT maize breeding programs, marker technology is now routinely deployed for four traits – resistance to MSV and MLN, haploid induction rate (Nair et al., 2017)and provitamin A enrichment (Prasanna et al., 2020). Validation of markers for kernel Zincand resistance to Turcicum Leaf Blight (TLB)and Grey Leaf Spot (GLS) in various breeding materialsand marker discovery efforts for tolerance to Striga and Fall Armyworm are presently underway.

3.1.2. Marker-assisted backcrossing (MABC): MABC is widely used for trait integration in elite genetic backgrounds, especially by maize breeding programs which maintain separate trait development and breeding pipelines. The most important commercial application of MABC in maize is to bring large-effect transgenes into elite inbred lines in instances where the use of forward bred transgenic elite lines would limit germplasm use to geographies where the technology is accepted. As a conventional breeding strategy, repeated backcrossing in general is less effective than strategies based on bi-parental F_2 or BC_1 population structure since the improved recipient parent is further improved with only one additional target trait while a 50-75% bi-parental population structure would enable several traits to be improved simultaneously.

In a situation where an important trait need emerges rapidly and available trait donors are non-adapted and lack elite performance for other critical traits, a repeated backcross plan can be effective. This was the case for maize lethal necrosis (MLN), a devastating disease that is endemic in eastern Africa since 2011. Most of the elite Africa-adapted CIMMYT maize inbred lines used in commercial products were highly susceptible to MLNand commercial hybrids in Kenya showed 70-100% yield loss under heavy MLN pressure. CIMMYT quickly identified resistance sources to MLN; however, these were not well adapted to eastern Africa. Since the elite germplasm pool was highly susceptible to MLN and important donor lines were non-elite and/or non-adapted, CIMMYT successfully undertook a large-scale MABC effort to transfer MLN resistance into more than 30 elite, but MLN-susceptible CIMMYT lines (**Figure 3**).

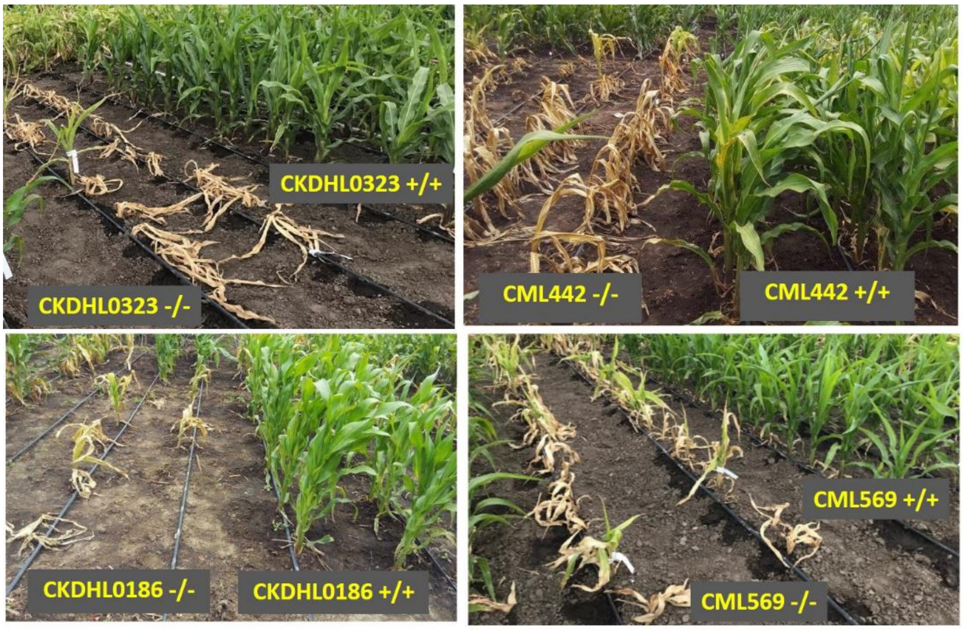


Figure 3. Conversion of elite but MLN-susceptible lines in Africa into MLN-resistant versions using MABC.

MABC has also successfully used for developing and deploying nutritionally enriched maize varieties (Prasanna et al. 2020). For example, at the ICAR-Indian Agricultural Research Institute, marker-assisted introgression of *opaque2* has recently led to the commercial release of three QPM hybrids viz., 'Pusa HM4 Improved', 'Pusa HM8 Improved' and 'Pusa HM9 Improved' (Hossain et al. 2018a). These hybrids possessed 3.49% and 0.84% lysine and tryptophan in protein, respectively. Also, pyramiding of *opaque2* and *opaque16* showed an increase of 64% lysine and 86% tryptophan over *o2*-based QPM hybrids. 'Pusa Vivek QPM9 Improved', India's first provitamin-A rich maize hybrid, was developed through introgression of *crtRB1*. This hybrid showed 8.15 µg/g of provitamin-A compared to 1-2 µg/g in normal maize (Muthuswamy et al. 2014; Hossain et al. 2018b).

3.1.3. Genomic selection: CIMMYT's maize GS strategy currently centers on a dynamic training set concept which seeks to use genotype and phenotype information from close relatives to get genomic estimated breeding values (GEBVs) of untested lines on a population-by-population basis (Vivek et al., 2017). In 2017, two CIMMYT maize breeding programs, one in Mexico and one in Kenya, piloted GS, where half of the testcrosses were placed in first year yield phenotyping trials as training sets while advancement decisions for the remaining half were based on GEBVs as prediction sets. In general, different bi-parental populations were approximately equally represented in both the prediction set and the training set. Customized training sets were initially attempted by clustering lines based on genotype and pedigree into sub-groups; however, given limited number of available lines in the prediction set and relatedness of experimental lines within testers, prediction was simply done within testers and within breeding programs.

3.2. Reducing Breeding Cycle Time

One of the conceptually simplest ways to increase genetic gain is to reduce the breeding cycle time – if selection intensity, accuracy and variability remain constant, halving cycle time will double the genetic gain (Xu et al., 2017). Breeding cycle times are typically 10 years or more in the tropics, compared to less than five in temperate regions (Challinor et al. 2016). Faster product cycle times are not only important for adaptation to the changing climates, but also for countering emerging pests and diseases.

"Speed breeding" has emerged as a novel technique for shortening generational cycles (Watson et al., 2018). Although establishing such facilities in developing countries may not be so easily possible, it is important to note that there are other possible alternatives to reduce the breeding cycle time. For example, the conventional off-season generation advancement method could be expanded to accommodate larger populations. Another important avenue is the doubled haploid (DH) technology in crops like maize. The integration of these innovative techniques with genome selection and high-throughput phenotyping will undoubtedly lead to accelerated genetic gain.

Derivation and use of DH lines, compared to conventionally-derived inbred lines, offers several advantages to the maize breeding programs, including simplified logistics and reduced costs in line development and maintenance (Prasanna et al., 2012). Use of DH lines in conjunction with molecular markers significantly improves genetic gains and breeding efficiency, by reducing cycle time and enhancing selection intensity. CIMMYT has optimized the protocol for maize DH line development in tropical genetic backgrounds, reducing significantly the time taken to develop parental lines (Prasanna et al., 2012). Tropically adapted first-generation haploid inducers with a haploid induction rate (HIR) of 5-8% were first developed by CIMMYT, in collaboration with the University of Hohenheim by transferring the maternal haploid induction trait from the temperate haploid inducers developed by University of Hohenheim. These tropicalized haploid inducers with better agronomic performance than the temperate haploid inducers in tropical conditions, were released in 2012, enabling the National Agricultural Research Systems (NARS) and small-and medium-enterprise (SME) private sector maize breeding programs in sub-Saharan Africa, Asia and Latin America to more easily adopt DH technology (Chaikam et al., 2019).

Recognizing the scope to further improve the first-generation tropically adapted inducer lines (TAILs) for various traits, CIMMYT initiated the development of second-generation haploid inducers for the tropics by transferring the haploid induction trait from first-generation TAILs to elite CIMMYT Maize Lines (CMLs), marker-assisted selection for higher haploid induction rateand phenotypic selection for superior agronomic performance (Chaikam et al., 2018). These inducer lines (called CIM2GTAILs) have high haploid induction rates (~10-13%), better agronomic performance in terms of plant vigor, synchrony with tropical populations, better standability, resistance to tropical foliar diseases and resistance to ear rots compared to first-generation TAILs in trials at different locations in Mexico and Kenya. Inducer hybrids developed using these CIM2GTAILs exhibit greater heterosis for plant vigor and pollen production while maintaining similar haploid induction rates as the parents and are well suited for open pollinations in isolation nurseries. These improvements contributed to a reduction in cost of DH production by 30% in CIMMYT's DH production pipeline (Chaikam et al., 2019).

Through dedicated maize DH facilities in Kenya and Mexico, CIMMYT Global Maize Program produces annually over 100,000 DH lines (up from less than 5000 in 2011) and selects the best out of these lines in breeding pipelines. Maize breeding programs of most of the national agricultural research systems (NARS) and small- and medium-enterprise (SME) seed companies in South and SE Asia are yet to tap the benefits of DH technology. Therefore, CIMMYT is in the process of establishing a Maize Double Haploid Platform at ARS-Kunigal in Karnataka, India, which will become functional by 2020.

3.3. High-throughput Field-based Phenotyping for Breeder-preferred Traits

Breeding trials are often extensive and therefore costly to monitor by conventional means. Field-based high-throughput phenotyping methods are needed to improve resource use efficiency of the breeding process while enabling to accurately characterize plant phenotypes of large populations in the field. Recent advances in sensor technology and image processing have provided new possibilities for high throughput phenotyping of breeder-preferred traits (Araus and Cairns, 2014; Araus et al., 2018). The most common form of sensors includes conventional digital red-blue-green (RGB), multispectral, hyperspectral, fluorescence and thermal cameras, deployed from aerial platforms (unmanned aerial vehicle, UAV) or at ground level using phenomobiles, phenopoles and hand-held sensors (Araus and Kefauver, 2018). The potential range of traits these advances open up is exceptional, particularly for low-cost options for breeder-preferred traits currently used within breeding programs to directly influence genetic gain (Araus and Kefauver, 2018).

For the CIMMYT maize breeding program, with a large phenotyping network across multiple countries in Africa, Asia and LatAm, a hybrid approach combining aerial sensing and ground-level sensing is being utilized for implementation of new phenotyping approaches to increase the accuracy of phenotyping while reducing field costs. For example, canopy senescence and disease severity are usually based on visual scores that are qualitative, often subjective and prone to human error. RGB images (taken from a UAV) are being used by CIMMYT maize program in Africa to derive a senescence index based on the ratio of senesced canopy to total canopy cover under low nitrogen conditions. Senescence index was highly correlated with grain yield compared to visual measurements of canopy senescence, while broad-sense heritability was equal to or higher than visual measurements (Makanza et al., 2018a,b). The time required for phenotyping time using a UAV was, thus, reduced by 95% relative to visual measurements.

3.4. Genome Editing

The field of genome/gene editing has progressed through several phases starting with oligo-mediated genome editing in the 1980s (Carroll, 2017). The main hurdle in widespread adoption of genome editing was the low frequency of the edited events, which makes progress painstakingly slow. A relatively new technique, clustered regularly interspersed short palindromic repeats (CRISPR) and CRISPR-associated protein 9 (Cas9), together referred to as CRISPR-Cas9, has revolutionized the field of genome editing because of its ease of use and a high success rate (Carroll, 2017). CRISPR-Cas9 system generally leads to three different outcomes: side-directed nuclease-1 (SDN1), where after a cut by the CRISPR-Cas9 of the host DNA non-homologous end joining (NHEJ) introduces random mutations during repair leading to gene inactivation in some instances; SDN2, which involves template-mediated sequence alteration to change the gene function; and SDN3, where a DNA fragment is inserted at a precise location in the genome (Podevin et al., 2013; Savitashev et al., 2015; Zhang et al., 2018).

In maize, a potential challenge in genome editing is the ability to transform genetically diverse elite lines. This hurdle has been recently overcome by including cell cycle genes in the transformation vector (Lowe et al., 2016, 2018). The ability to transform the tropical lines has paved the way to use SDN1 or SDN2 gene editing approaches directly in the commercial lines. In partnership with Corteva, CIMMYT is presently exploring gene editing for quickly converting elite but MLN-susceptible lines into MLN-resistant versions.

With the progress made in the development of genome-editing tools (Zhang et al., 2018), genome editing certainly promises to play a key role in speeding up trait enrichment in crop breeding programs. Lassoued et al. (2019) presented the results of an expert survey on the potential benefits of genome-edited crops compared to those developed through genetic modification (GM) and conventional breeding. The survey results revealed a consensus among experts on the enhanced agronomic performance and product quality of genome-edited crops over alternatives. Nevertheless, we must take into account government regulations and consumer acceptance around the applications of genome editingand ultimately, commercialization of genome-edited crops.

4. Modernization of Breeding Programs

The increasing availability of breeding related information, including pedigree, phenotypic and genotypic, coupled with environmental data, brings both opportunities and challenges in effectively managing and utilizing such information in breeding programs (Xu et al. 2017). This necessitates development of integrated platforms or one-stop data portals that can effectively bring together high-density genotyping, high-throughput and precision phenotyping and multi-dimensional environment profiling along with a suite of decision support tools to drive modern breeding programs. Data integration from multiple sources is one of the key components in developing breeding informatics systems. Efficient breeding informatics systems will need to include data curation tools, automated quality control workflows, data processing pipelines, visualization tools and simple and user-friendly data analytical and mining tool kits. This is one area where the tropical maize breeding programs are clearly lagging behind, since most of the data accumulated as part of the breeding cycles are maintained as flat files which are not in queryable databases; hence, breeding programs are not able to make maximum use of the data developed through multiple breeding cycles.

Breeding informatics has been revolutionized with significant changes in data generation, storage, scale, dimension, throughputand precision, distinctly different from other big data in data properties, collection, treatment, analysis, mining and utilization. Modern breeding is now becoming increasingly integrated with programmed breeding pipeline, agricultural engineering, facilities with artificial or controlled environments and biological modelling/simulation, to meet human demands for high yielding, improved quality, resource-use efficient and environment-friendly crop varieties. These trends will rely on artificial intelligence (AI)-guided agriculture to complete the conversion of breeding from big data-driven to AI-driven. Future breeding programs, including those in maize, could become AI system-based, with strong influence of both breeding informatics and breeders' knowledge of germplasm.

5. Improving Resource Use Efficiency and Saving Production Costs

The future food and nutrition demand of growing population has to be met mainly through increasing yield per unit area with lesser external inputs (labor, water and energy) while protecting the environment (Choudhary et al., 2018a). The soil organic carbon (SOC) contents in most cultivated soils of India is less than 5 g/kg compared to 15-20 g/kg in uncultivated virgin soils (Bhattacharyya et al., 2000); this is attributed to intensive tillage, removal/burning of crop residues, mining of soil fertility and intensive monotonous cropping systems. To sustainably increase the food production while conserving precious natural resources, we need a multi-pronged strategy that includes: (i) bridging the yield gaps through more efficient agronomic management; (ii) diversifying the resource-intensive and less efficient crops/cropping systems with resource use efficient production systems; and (iii) transitioning from a commodity-centric approach to a market-inclusive system-based management innovations (Jat et al., 2016; Lal, 2016).

"Sustainable intensification" has to be an important component of the overall strategy for ensuring food security, poverty alleviation, health for all, rural development, enhancing productivity, improving environmental qualityand preserving natural resources. Developing and deploying a portfolio of sustainable intensification practices, integrating basic elements of precision-conservation agriculture, integrated nutrient managementand scale-appropriate mechanization can immensley help in improving efficient use of resources (soil, labor, water and nutrients) and saving production costs (Lal, 2016). For instance, scale-appropriate mechanization has tremendous potential in terms of social benefits like increased income, employment, food security, less drudgeryand attracting youth to agriculture. Adoption of agricultural mechanization in Africa, Asiaand Latin America has reaped many benefits, although much remains to be done in scaling-up and scaling-out. For example, farmers in many parts of Africa and Asia are saving up to 45 days of labor with direct-seed machinery in conservation agriculture systems, compared to conventional methods.

6. Tackling Malnutrition and Hidden Hunger through Dietary Diversification and Biofortification

Malnutrition takes many forms: undernutrition, micronutrient deficiencies, obesity and being overweight. Undernutrition is the largest contributor to child mortality worldwide; nearly 25 per cent of children under the age of five are chronically malnourished. However, in South Asia and SSA, home to three-quarters of these children, the figure is 40 per cent. More than 2 billion people suffer from micronutrient malnutrition or "hidden hunger". India is home to one-fourth (approximately 208 million) of the world's total (approximately 800 million) of under-nourished people. Anaemia affects more than half of the pre-school children and more than half of the pregnant women.

Breeding nutritionally-enriched crop varieties ("Biofortification") and improvements in soil health can raise the nutrient value of crops, as can better storage, preservation and processing. Improved production, processing and marketing efficiency, as well as reduction of post-harvest waste, can reduce the relative prices and/or the amount of time it takes to prepare more nutritious foods, making them more attractive as part of the diet. Significant progress has been made in developing, testingand deploying maize cultivars biofortified with quality protein maize (QPM), provitamin Aand kernel zinc (Prasanna et al. 2020).

In India, molecular marker-assisted backcross breeding (MABB) has been successfully used to develop and release several nutritionally-enriched maize cultivars. A single-cross QPM hybrid, "Vivek QPM-9" was first developed through MABB and officially released in 2008, possessing 41% more tryptophan and 30% more lysine over the original hybrid (Vivek Hybrid-9). More recently, QPM versions of three popular non-QPM hybrids, viz., "Pusa HM-4 Improved", "Pusa HM-8 Improved" and "Pusa HM-9 Improved" have been released in 2017 for commercial cultivation in India, possessing nearly double the concentrations of lysine and tryptophan as compared to normal maize. Using MABB, an elite maize hybrid with a stack of nutritional quality traits (QPM and Provitamin A), "Pusa Vivek QPM-9 Improved", was developed by ICAR-Indian Agricultural Research Institute (IARI)and has been officially released in India in 2017 for commercial cultivation. Three more MABB-derived hybrids, including one provitamin A hybrid, "Pusa Vivek Hybrid-27 Improved"and two QPM + provitamin A-enriched hybrids, "Pusa HQPM5 Improved" and "Pusa HQPM7 Improved", developed by ICAR-IARI, have been approved for release in India in 2019 (Prasanna et al., 2020).

CIMMYT, in collaboration with public and private sector partners in Mexico, Guatemala, Nicaragua, El Salvador, Honduras and Colombia, has been working on development and deployment of elite high-Zinc (Zn) maize cultivars. So far, four high-Zn maize cultivars (two hybrids and two synthetics) have been released in Latin America (Prasanna et al., 2020).

Intensive interdisciplinary work and more effective integration of national and international research efforts are key for enhanced development and dissemination of biofortified maize varieties. For such cultivars to succeed in the market, it is important to understand the market dynamics. Value chains that effectively link the farmers to the processors and the consumers need to be improved. Only through such linkages can the value of biofortified crop cultivars be fully exploited, malnutrition alleviatedand new markets opened (Prasanna et al., 2020).

7. Protecting Genetic Gain from Devastating Pathogens and Insect-pests

Pathogens and insect-pests have severe and cross-cutting negative impacts, particularly affecting farmers' incomes and livelihoods. Their capacity to rapidly evolve and proliferate pose a huge challenge for increasing genetic gain in stress-prone environments, especially in the tropics. There is a significant need for implementation of development and implementation of multi-disciplinary, multi-institutionaland sustainable strategies for devastating diseases and pests, to counter the threat to food and nutritional securityand the livelihoods of populations.

A most recent example of an invasive and highly destructive insect-pest affecting farmers across Africa and Asia is the Fall Armyworm (*Spodoptera frugiperda*; FAW). FAW has been prevalent in the Americas for several decades but was reported for the first time in West Africa in 2016. Within two years, FAW incidence had already been reported in more than 40 countries across Africa. The pest was reported for the first time in India in mid-2018and subsequently reported in several other Asian countries. FAW attacks primarily the maize crop and has potential to feed on more than 80 other crops, including sorghum and sugarcane. Indiscriminate and unguided use of toxic synthetic pesticides is reported across Africa and Asia for FAW control, which poses serious threat to environment, animal and human health, besides affecting the natural enemies of the pest. Therefore, it is extremely important to develop, testand urgently deploy science-based, integrated pest management (IPM) technologies/management practices, including host plant resistance (both native genetic resistance and transgene-based resistance) to FAW, environmentally-safer synthetic pesticides, biopesticides and botanicals, besides low-cost cultural control and agro-ecological approaches (Prasanna et al., 2018).

8. Conclusions

We need to address with much-needed urgency an array of challenges affecting Indian agriculture, including the increasing frequency of climatic variabilities/extremes, extensive malnutrition, reduced soil health, fragility of our natural resource systemand devastating diseases and insect-pests. Intensive multi-institutional and multi-disciplinary efforts are required to discover, validate and deploy innovative and sustainable technologies that can improve crop productivity, reduce production costsand improve the incomes of smallholder farmers. Building climate resilience warrants effective integration of climate-resilient crop varieties, climate-smart agronomic management practicesand effective implementation of policies to help reduce environmental and ecological footprints of agricultural practices.

Scientific institutions must enhance the the pace, precision and efficiency of breeding programs through judicious and effective integration of modern tools/strategies, including high-density genotyping, high throughput and precision phenotyping, speed breeding, molecular marker-assisted and genomic selection-based breedingand knowledge-led decision-support systems. Seed systems need to be further strengthened to become more market-oriented and dynamicand for providing smallholders with greater access to affordable climate-resilient and nutritionally enriched improved seed. Understanding the smallholder farmers' constraints for adoption of modern technologies, enhancing affordability and access to quality agricultural inputsand improving their linkages to the input and output markets should be accorded top priority.

Technologically, we are living in exciting times. Genomics-assisted breeding, genome editing, speed breeding, remote sensors, satellite imagery, drones, artificial intelligence, machine learning, decision support tools, information and communication technologies, are only a few of the innovations that one can mention that are impacting various spheres of life, including agriculture. For instance, remote sensors, satellite imagery and drones can monitor plant health, soil conditions, temperature, nitrogen utilization, disease and pest infestaton levelsand much more. Goldman Sachs predicts that the agricultural sector will be the second largest user of drones in the world in the next five years. Recruitment of state-of the-art technologies for developing imrpoved varieties, effective trial management practicesand mechanization and digital tools/devices are expected to enhance the rate of genetic gain in farmers' fields (Cobb et al., 2019). Genome editing is another powerful technology to transform modern breeding. How well we can use such innovations for improving the livelihoods of farmers, especially smallholders, will determine how fast we can translate the vision of making agriculture profitable and sustainable. Breeding programs should be constantly appraised and revised by incorporating new innovations. Furthermore, the efficiency and effectiveness of the breeding programs should be monitored by employing metrics designed to measure the impacts of breeding outcomes (= improved varieties) on the ultimate users – the farmers.

References

Araus JL, Cairns JE (2014) Field high-throughput phenotyping, the new crop breeding frontier. *Trends in Plant Science* 19: 52-61.

Araus JL, Kefauver SC (2018) Breeding to adapt agriculture to climate change: affordable phenotyping solutions. *Current Opinion in Plant Biology* 45 Part B: 237-247.

Araus JL, Kefauver SC, Zaman-Allah M, Olsen MS, Cairns JE (2018) Translating high throughput phenotyping into genetic gain. *Trends in Plant Science* 23:451-466.

Cairns JE, Sonder K, Zaidi PH, Verhulst N, Mahuku G, Babu R, Nair SK, Das B, Govaerts B, Vinayan MT, Rashid Z, Noor JJ, Devi P, San Vicente F, Prasanna BM (2012) Maize production in a changing climate: impacts, adaptation and mitigation strategies. *Advances in Agronomy* 114: 1-58.

Cairns JE, Prasanna BM (2018) Developing and deploying climate-resilient maize varieties in the developing world. *Current Opinion in Plant Biology* 45 (Part B): 226-230.

Carroll D (2017) Genome editing: past, presentand future. *The Yale Journal of Biology and Medicine* 90: 653-659.

Chaikam V, Molenaar W, Melchinger AE, Prasanna BM (2019) Doubled haploid technology for line development in maize: technical advances and prospects. *Theoretical and Applied Genetics* 132: 3227-3243.

Chaikam V, Nair SK, Martinez L, Lopez LA, Utz HF, Melchinger AE, Prasanna BM (2018) Marker-assisted breeding of improved maternal haploid inducers in maize for the tropical/subtropical regions. *Frontiers in Plant Science* 9: 1527.

Challinor AJ, Koehler A-K, Ramirez-Villegas J, Whitfield S, Das B (2016) Current warming will reduce yields unless maize breeding and seed systems adapt immediately. *Nature Climate Change* 6: 954-958.

Chand R (2012) Agricultural R&D for Next Generation – ICAR Vision 2050. Agricultural Universities Vice-Chancellors and ICAR Directors Meet.

Choudhary KM, Jat HS, Nandal DP, Bishnoi DK, et al. (2018a) Evaluating alternatives to rice-wheat system in western Indo-Gangetic Plains: Crop yields, water productivity and economic profitability. *Field Crops Research* 218: 1-10.

Cobb JN, Juma RU, Biswas PS, Arbelaez JD, Rutkoski J, Atlin G, Hagen T, Quinn M, Ng EH (2019) Enhancing the rate of genetic gain in public-sector plant breeding programs: lessons from the breeder's equation. *Theoretical and Applied Genetics* 132: 627-645.

Cooper M, Messina CD, Podlich D, et al. (2014) Predicting the future of plant breeding: Complementing empirical evaluation with genetic prediction. *Crop Pasture Science* 65: 311–336.

Deutsch CA, Tewksbury JJ, Tigchelaar M, Battisti DS, et al. (2018) Increase in crop losses to insect pests in a warming climate. *Science* 361: 916–919.

Edmeades GO, Bolaños J, Chapman SC, Lafitte HR, Banziger M (1999) Selection improves drought tolerance in tropical maize populations: I. Gains in biomass, grain yieldand harvest index. *Crop Science* 39:1306–1315.

Edmeades GO, Trevisan W, Prasanna BM, Campos H (2017) Tropical maize (*Zea mays* L.). In: Genetic Improvement of Tropical Crops, Springer, pp. 57-109.

Falconer DS, Mackay TFC (1996) Introduction to Quantitative Genetics. 4th Edition, Addison Wesley Longman, Harlow.

Gilliham M, Able JA, Roy SJ (2017) Translating knowledge about abiotic stress tolerance to breeding programmes. *Plant Journal* 90: 898-917.

Hansen J, Hellin J, Rosenstock T, Fisher E, Cairns J, et al. (2019) Climate risk management and rural poverty reduction. *Agricultural Systems* 172: 28-46.

Hossain F, Muthusamy V, Pandey N, Vishwakarma AK, Baveja A, et al. (2018a) Marker-assisted introgression of *opaque2* allele for rapid conversion of elite maize hybrids into quality protein maize. *Journal of Genetics* 97: 287-298.

Hossain F, Muthusamy V, Zunjare RU (2018b) Molecular breeding for development of biofortified maize hybrids in India. In: Prasanna BM, Das A, Kaimenyi KK (eds) Book of Extended Summaries, 13th Asian Maize Conference and Expert Consultation on Maize for Food, Feed, Nutrition and Environmental Security. Ludhiana, India, October 8–10, 2018. CIMMYT, Mexico D.F., pp 210-220.

Jat ML, Dagar JC, Sapkota TB, Singh Y, et al. (2016) Climate change and agriculture: adaptation strategies and mitigation opportunities for food security in South Asia and Latin America. *Advances in Agronomy* 137: 127–236.

Lal R (2016) Feeding 11 billion on 0.5 billion hectare of area under cereal crops. *Food Energy Security* 5: 239–251.

Lowe K, La Rota M, Hoerster G, Hastings C, Wang N, et al. (2018) Rapid genotype "independent" *Zea mays* L. (maize) transformation via direct somatic embryogenesis. *In Vitro Cellular & Developmental Biology-Plant* 54: 240-252.

Lowe K, Wu E, Wang N, Hoerster G, Hastings C, et al. (2016) Morphogenic regulators *Baby boom* and *Wuschel* improve monocot transformation. *Plant Cell* 28: 1998-2015.

Makanza R, Zaman Allah M, Cairns J, Magorokosho C, Tarekegne A, Olsen M, Prasanna B (2018a) High-throughput phenotyping of canopy cover and senescence in maize field trials using aerial digital canopy imaging. *Remote Sensing* 10: 330.

Makanza R, Zaman-Allah M, Cairns JE, Eyre J, Burgueño J, Pacheco A, Diepenbrock C, Magorokosho C, Tarekegne A, Olsen M, Prasanna BM (2018b) High-throughput method for ear phenotyping and kernel weight estimation in maize using ear digital imaging. *Plant Methods* 14: 49.

Muthusamy V, Hossain F, Nepolean T, Choudhary M, Saha S, Bhat JS, Prasanna BM, Gupta HS (2014) Development of β-carotene rich maize hybrids through marker-assisted introgression of β-carotene hydroxylase allele. *PLoS One* 9: 1–22

Nair SK, Raman B, Prasanna BM (2018) Genomic and enabling technologies for enhancing genetic gain in tropical maize. In: Prasanna BM, Das A, Kaimenyi KK (eds) Book of Extended Summaries, 13th Asian Maize Conference and Expert Consultation on Maize for Food, Feed, Nutrition and Environmental Security. Ludhiana, India, October 8–10, 2018. CIMMYT, Mexico D.F., pp. 15-27.

Podevin N, Davies HV, Hartung F, Nogue F, Casacuberta JM (2013) Site-directed nucleases: a paradigm shift in predictable, knowledge-based plant breeding. *Trends in Biotechnology* 31: 375-383.

Prasanna BM, Chaikam V, Mahuku G (2012) Doubled Haploid Technology in Maize Breeding: Theory and Practice. Mexico D.F.: CIMMYT.

Prasanna BM, Huesing JE, Eddy R, Peschke VM (eds) (2018) Fall Armyworm in Africa: A Guide for Integrated Pest Management, First Edition. Mexico, CDMX: CIMMYT.

Prasanna BM, Palacios-Rojas N, Hossain F, Muthusamy V, Menkir A, et al. (2020) Molecular breeding for nutritionally enriched maize: status and prospects. *Frontiers in Genetics-Nutrogenomics* [In Press].

Lassoued R, Macall DM, Hesseln H, Phillips PWB, Smyth SJ (2019) Benefits of genome-edited crops: expert opinion. *Transgenic Research* 28: 247-256.

Savitashev S, Young J, Schwartz C, Gao H, Falco SC, Cigan AM (2015) Targeted mutagenesis, precise gene editing and site-specific gene insertion in maize using Cal9 and guide RNA. *Plant Physiology* 169: 931-945.

Singh P (2019) Feeding 1.7 billion. Presidential Address: Foundation Day and 26th General Body Meeting, National Academy of Agricultural Sciences (NAAS), 5th June 2019.

Shroff R (2019) India: An Agricultural Powerhouse. The Sunday Guardian, May 12-18, New Delhi.

Tesfaye K, Zaidi PH, Gbegbelegbe S, Boeber C, et al. (2017) Climate change impacts and potential benefits of heat-tolerant maize in South Asia. *Theoretical and Applied Climatology* 130: 959-970.

Tesfaye K, Kruseman G, Cairns JE, Zaman-Allah M, et al. (2018) Potential benefits of drought and heat tolerance for adapting maize to climate change in tropical environments. *Climate Risk Management* 19: 106-119.

Xu Y, Li P, Zou C, Lu Y, Xie C, Zhang X, Prasanna BM, Olsen MS (2017) Enhancing genetic gain in the era of molecular breeding. *Journal of Experimental Botany* 68: 2641-2666.

Zhang Y, Massel K, Godwin ID, Gao C (2018) Applications and potential of genome editing in crop improvement. *Genome Biology* 19: 210.

NEED FOR CROP DIVERSIFICATION WITH MAIZE IN PUNJAB

Sujay Rakshit, S.L. Jat and Chaikkappa G.K.
ICAR-Indian Institute of Maize Research, Ludhiana
s.rakshit@icar.gov.in

Maize is the third most important cereal crop after wheat and rice in India. Besides as food crop, it is consumed more as feed, fodder and large scale importance as an industrial crop. Worldwide maize is cultivated on over 185 million hectares in 170 countries with a productivity of 5.62 t/ha. USA and China contribute around 35 and 21 per cent of total global production, respectively. India ranks fourth in area and sixth in the production. The productivity of maize in India (3.1 t/ha) is much lower than the world average. However, per day productivity of maize in India is comparable to many temperate countries. In India the maize production has recorded phenomenal growth which was happened both due to area expansion and adoption of improved production technologies like inroads of hybrids and better crop management practices. Currently India produces over 28 million MT of maize, of which roughly 60% is used as feed (poultry and animal feed), 14% for industrial purposes, around 13% for food, 7% as processed food and 6% for other purposes including seed. Increasing demand for maize particularly in feed industry has contributed towards increased production. By 2025 India is projected to require about 32 million MT of maize solely in feed industry. Further, the starch industry will require additional 15 million MT by 2025 from the present level of 4.25 million MT. By 2025 the overall demand for maize is projected to be 50 million MT, which is a big feat to be achieved.

Maize is predominantly a rainy season (*kharif*) crop in India. Traditionally it used to be grown in the states of Punjab, Uttar Pradesh, Bihar, Rajasthan and Madhya Pradesh. However, after 1980s, the area shifted more towards peninsular region and currently this region represents nearly 40% of the total area under maize and over 52% of production. The major maize growing states are Karnataka (14.8%), Maharashtra (10.9%), Madhya Pradesh (10.8%), undivided Andhra Pradesh (10.4%), Rajasthan (10.6%), Uttar Pradesh (8.3%), Bihar (7.9%), Gujarat (5.0%) and Tamil Nadu (3.6%), accounting for nearly 80% of the total maize area of the country. Before the era of green revolution in the 1960s, Punjab was one of the major maize growing states in India. The state constituted 9% of the total maize area of the country with 13% production during mid 1960s. However, over a period of 50 years from 1966-2016 the trend has changed completely. Currently Punjab contributes 1.5% of the total maize produced in India from little over one per cent (1.2%) maize area of 9.8 mha in the country. In 1966, the total maize area in Punjab was around 4.44 lakh hectares which increased to 5.77 lakh hectares in 1975-76. Subsequently from 1975 onwards the maize area was decreasing gradually and currently it is around 1.14 lakh hectares. On the contrary, the area under rice mainly during kharif season has increased significantly from 2.85 lakh hectares in 1966-67 to 30.65 lakh hectares (2017-18) which is whopping 74.41% of the net sown area (41.45 lakh ha) of Punjab. The above statistics indicate that Punjab is predominantly under rice-based cropping system during kharif season with extremely less area under other crops. Thus, the state of Punjab has slowly shifted from the traditional crops like maize, pearl millet, pulses and oilseeds to mainly rice with little or negligible area under other traditional crops. The shift was mostly driven by unfavourable policy support to the other crops and non-availability of high yielding cultivars in these crops. In fact the adoption of the high-yielding rice cultivars in 1970s with expansion of irrigation facilities and usage of fertilizer and pesticide brought green revolution in Punjab. This increased adoption of rice in Punjab and Haryana helped in ensuring food security of the country. Further, the favourable government policies of establishment of storage, marketing, milling industry with no pricing for water and electricity and assured purchase of rice have given impetus to increase its acreage at very fast rate.

The extremely large area under rice during kharif season in Punjab over a period of 5 decades has led to one of the major serious ecological imbalance in the region like lowering water table. In addition, the agriculture sector in Punjab is also facing other challenges like increasing imbalances soil fertility, appearance of new pests and weeds, escalation in costs of production, falling profitability in farming, increasing incidence of landlessness and indebtedness among the farmers etc. Further, there are emerging uncertainties of weather, climate change and global warming for which impact on agriculture of Punjab is yet to be foreseen. The above scenarios indicate that the state of Punjab is facing the challenge of long-term sustainability of agriculture. Therefore, diversification of the rice with maize could address sustainability of agriculture in Punjab.

Maize for diversification

The major advantages of shifting from rice to maize is that, maize being less water demanding crop than rice (almost half) could immediately address the issue of lowering water table. The other major issue maize could address immediately is the current issue of increased air pollution in Punjab and nation as a whole due to burning of rice-straw. Further, maize cultivation can address several other issues which promote ecological balance and environmental sustainability like maintaining the soil fertility and soil eco-system through maize based conservation agriculture. The adoption of zero-tillage resource conservation crop production practices could reduce green house gas emission substantially which will further improve environmental quality. In addition several ancillary advantages can be reaped by farmers through maize cultivation like saving of electricity on water pumping, advancing wheat panting which will help in increased wheat productivity by minimizing risk of terminal heat stress, less use of pesticide in maize production will reduce the ground water pollution and related effects. The required technologies like suitable high-yielding single cross hybrid maize cultivars (7-10 t/ha), efficient weed management system, machineries for mechanized cultivation of maize and conservation agriculture practices are available to promote maize as alternative crop for crop diversification in Punjab.

Strategies for maize based crop diversification in Punjab

Mapping of target area

Identification of ecologically vulnerable pockets of the state should be the priority to target the most appropriate technology like single cross hybrid technology. Several high yielding single cross hybrids have been released for commercial cultivation for the state of Punjab. Targeting such hybrids to divert rice-dominated cropping system could be one strategy to prevent further ecological imbalances. The mapping could be as precise as possible at Tehshil to block level using most advanced information and data like satellite images.

Policy intervention

The combination of push and pull factors has to be implemented by government to convince farmers to shift from rice cultivation to alternative crops like maize. The following intervention from the government could certainly create an impact to bring crop diversification in Punjab through maize.

a. Procurement of farm produce – Government has to ensure procurement of maize at minimum support price (MSP) just like rice or wheat from the farm gate of farmers. The policy would encourage farmers to go for maize cultivation as final disposal is ensured.
b. Specialty corn and livestock production – The demand for specialty corns like sweet corn, baby corn and popcorn is increasing. Presently in Punjab baby corn industry in Ludhiana is already exporting processed and fresh packed baby corn in large quantity to other countries. Considering the availability of required infrastructure, like airports with direct cargo flights to European countries there is scope to promote specialty corn cultivation to bring maize led diversification in existing cropping system of Punjab. Further, it is known fact that Punjab has organized livestock / dairy farms. Establishing linkages between specialty corn cultivation like baby corn and sweet corn with dairy farms could further boost livestock industry.
c. Silage maize – Maize is one of the best crops for silage making. The organized dairy industry in Punjab could be better supplied with high quality maize silage by promoting maize cultivation for fodder and silage making. The cultivation of fodder and silage maize is another avenue to bring diversification in the existing un-sustainable rice-based cropping system of Punjab.
d. Arrangement of community based machineries – What and rice are cultivation is largely mechanized; in order to promote maize cultivation in the state, government has to encourage and support to create facilities like community based machineries to undertake mechanized cultivation of maize. Combined harvester, dehusker and maize sheller may be made available to the farmers on custum-hire basis. Maize grain dryers and silos need to be made available at block level, while small scale storage bins need to be provided to small farmers.
e. Development of value chain – The government support to establish end-user industries like food, feed and starch industries and also storage facilities would certainly encourage entrepreneurship and attract investment in agriculture and create competition in the market.
f. Crop insurance and differential price support – The government has to create competitive crop insurance comparable with rice encourage maize cultivation. Since a organized market for maize is yet to be established and the current economics of maize cultivation vis-a-vis rice cultivation favours rice, the differential profit may be compensated to the farmers growing maize for incentivising maize cultivation in the state. Savings on account of electricity and ground water may diverted to the maize growers.

The maize based crop diversification in Punjab is the need of the hour to sustain and ensure food security of the nation as a whole and also maintain the soil health, productivity potential, environmental quality and ecological balance of agricultural land in long-run. Thus the concerted efforts by government to deploy available technologies like high yielding hybrids, crop production practices through strong policy intervention could bring crop diversification in Punjab.

Modified from presentation made in FICCI Conclave on FICCI North India Agri-Conclave 2019: Crop Diversification with Maize, Dec. 10, 2019

CROP DIVERSIFICATION – TO ENSURE AND PROMOTE SUSTAINABLE NATURAL RESOURCES USE

Sain Dass[1], S.L. Jat[2], Chikkappa G. Karjagi[2], C.M. Parihar[3], Mukesh Choudhary[4] and Ramesh Kumar[4]
[1]Ex-Director, ICAR-Indian Institute of Maize Research, New Delhi
[2]ICAR-Indian Institute of Maize Research , New Delhi
[3]ICAR-Indian Agricultural Research Institute, New Delhi
[4]ICAR-Indian Institute of Maize Research, Ludhiana
sdass2010@gmail.com

Maize is known as queen of cereals because it has the highest genetic yield potential among the cereals. It is cultivated on nearly 187 million ha in about 166 countries having wider diversity of soil, climate, biodiversity and management practices that contributes nearly 40% (1135 million t) in the global grain production during 2017 (FAOSTAT, 2019). India rank 4th in area while stood at 6th position in maize production largely because of the average productivity in India is less than 2.5 t ha-1. The lesser maize productivity in India is largely due to >75% of its 9.63 million ha cultivated area is rainfed mainly during kharif season which is a gamble of South-West monsoon. In India maize is the third most important cereal food crop after rice and wheat. It is used as human food (24%), animal feed (11%), poultry feed (52%). The important maize based cropping systems in India under irrigated and rainfed conditions of different agro-climatic zones being practiced are given in Table 1. Among different maize based cropping systems, maize-wheat ranks 1st having 1.8 m ha area mainly concentrated in rainfed ecologies and is the 3rd most important cropping systems in India. The other major maize systems in India are maize-mustard, maize-chickpea, maize-maize, cotton-maize etc. Recently, due to changing scenario of natural resource base, rice-maize has emerged a potential maize based cropping system in peninsular and eastern India. In *peri*-urban interface, maize based high value intercropping systems are also gaining importance due to market driven farming. Further, maize has compatibility with several crops of different growth habit that led to development of various intercropping systems in our country.

Table 1. Maize based sequential cropping systems in different ago-climatic zones of India

Agro-climatic region	**Cropping system**	
	Irrigated	**Rainfed**
Western Himalayan Region	Maize-wheat Maize-potato-wheat Maize-wheat-green gram Maize-mustard Maize-sugarcane	Maize-mustard Maize-legumes
Eastern Himalayan Region	Summer rice-maize-mustard Maize-maize Maize-maize-legumes	Sesame-Rice+maize
Lower Gangetic Plain region	Autumn rice-maize Jute-rice-maize	Rice-maize
Middle Gangetic Plain region	Maize-early potato-wheat-mungbean Maize-wheat	Maize-wheat

Agro-climatic region	Cropping system	
	Irrigated	Rainfed
Upper Gangetic Plain region	Maize-wheat-mungbean Maize-wheat-urdbean Maize-sugarcane-mungbean Maize-wheat Maize-wheat-mungbean Maize-potato-wheat Maize-potato-sunflower Maize-potato-onion Maize-potato-sugarcane-ratoon Rice-potato-maize	Maize-wheat Maize-barley Maize-safflower
Trans Gangetic Plain region	Maize-wheat Maize-wheat-mungbean Maize-potato-wheat Maize-potato-sunflower Maize-potato-onion Mungbean-maize-toria-wheat Maize-early potato-late potato-mungbean	-
Eastern plateau & hills region	Maize-groundnut-vegetables Maize-wheat-vegetables	Rice-potato-maize Jute-maize-cowpea
Central plateau & hills region	Maize-wheat	Maize-groundnut
Western plateau & hills region	Sugarcane + Maize	
Southern plateau & hills region	Maize-rice Rice-maize	Sorghum-maize Maize-sorghum-Pulses Maize-potato-groundnut
East coast plain and hills region	Rice-maize-pearlmillet Maize-rice Rice-maize Rice-rice-maize	Maize-maize-pearlmillet Rice-maize + cowpea
West coast plain and hills region	Maize-pulses Rice-maize	Rice-maize Groundnut-maize
Gujarat plains and hills region	Maize-wheat	Rice-maize
Western dry region	Maize-mustard Maize-chickpea	Maize+legumes
Island region	Rice-maize	Maize-rice Rice-maize + cowpea Rice-maize-urdbean Rice-rice-maize

The adoption of maize in low rainfall areas and under lowering water table situations is coming up at very fast rate. The maize is a solution crop for the lowering water table in the *rabi* rice growing areas of Andhra Pradesh, Karnataka and Tamil Nadu and also for the low rainfall areas of upland rice in the states of West Bengal and Odisha (Figure 1). Similarly, maize is solution for the heat stress in wheat causing significant yield reduction in the Northern India. The favourable temperature in the *rabi* season of the states like West Bengal, Odisha, Rajasthan, Gujarat and Madhya Pradesh offers a great potential for maize hybrid seed production and areas under seed production is coming up very fast in these areas in recent years. The remunerative seed production in these states will cater the needs of the states as well as have potential for export to neighboring states and countries. The cultivation of spring maize after harvest of potato is now became reality in North Indian states like Punjab, Haryana and western Uttar Pradesh and giving more productivity.

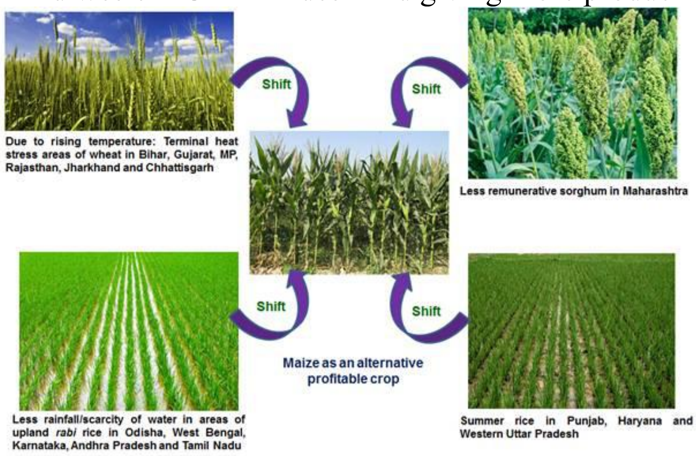


Figure 1: Maize as better remunerative alternate crop in era of climate change

Maize has wider adaptability and compatibility under diverse soil and agro-climatic conditions and hence it is cultivated in sequence with different crops under various seasons and agro-ecologies of the country. Hence, it is considered as one of the potential driver of crop diversification under different situation. In recent years due to rising temperature during grain filling period of wheat causing terminal heat stress in central and eastern Indian states covering parts of Bihar, Gujarat, Madhya Pradesh, Rajasthan, Jharkhand and Chhattisgarh which provides an opportunity to select maize during *rabi* season. The less remunerative sorghum production area in Maharashtra is also shifting in maize. In Odisha, maize is coming up as a potential alternative crop in low rainfall areas of rice cultivation during *kharif*. Likewise, the *rabi* rice areas in the states of Odisha, West Bengal, Karnatakaandhra Pradesh and Tamil Nadu facing problem of ground water shortage and the maize is coming up as a potential crop. The cultivation of spring maize after harvest of potato and sugarcane has become reality in some of the states (Punjab, Haryana, western UP, lower valley of Uttrakhand) and emerged as an alternative profitable crop replacing summer rice.

Maize is a solution for emerging problems of depleting water table and terminal heat stress in winter crops. It also provides opportunity for farm mechanization and conservation agriculture which results into timely farm operation, reducing soil erosion, improving soil health, reducing cost of cultivation and increasing farm profitability.

References

Dass S, Yadav VK, Kwatra A, Sekhar JC, Yadav Y (2009). Technical Bulletin Baby Corn: Production Technology and Value Addition. Directorate of Maize Research, New Delhi.

Dass S, Jat ML, Yadav VK, Sekhar JC, Singh DK (2009). Technical Bulletin. Quality Protein Maize for Food and Nutritional Security in India. Directorate of Maize Research, New Delhi,

Dass S, Jat SL, Chikkappa GK Parihar CM, Kumar B and Singh AK (2012). Maize improvement towards food security: genetic and technological perspectives. In: conference programme book of *1st ICC India Grains Conference* organized by ICC in partnership with ICRISAT at New Delhi from 16-18th January, 2012. pp 24-25

STRESS-RESILIENT MAIZE: DOWNSIZING RISKS REALIZING YIELD POTENTIAL OF RAINFED *KHARIF* MAIZE

P.H. Zaidi
CIMMYT-Asia Maize Program, Hyberabad
phzaidi@cgiar.org

In India, maize is largely grown as rainfed crop, which is prone to the vagaries of monsoon rains and associated abiotic and biotic constraints. Moisture availability is seldom adequate for rainfed maize, as erratic/un-even distribution pattern of monsoon rains often cause intermittent drought or excessive moisture/waterlogging at different crop growth stage(s). Uncertainty of assured returns often discourage rainfed farmers to invest on improved seed and recommended inputs, which further add in poor yields of rainfed maize. Rainfed systems are largely dependent on prevailing weather conditions and therefore extremely vulnerable to climate change effects. Studies suggested that Asian tropics will experience increasing frequency of extreme weather conditions with high variability beyond current capacity to adapt (ADB, 2009; Cairns et al., 2012). Such impacts are evident in form of shifting seasons and significant inter-annual variation in rainfall, temperature etc. with increased frequency of extreme weather causing severe drought, water-logging and heat stress (Zaidi et al., 2020)and also reduced number of rainy days per year (Kashyapi et al., 2012).

In recent years the Indian tropics have experienced frequent and widespread drought years, coupled with increased day/night temperatures during the main maize growing season, apart from scattered drought/waterlogging/heat almost every year in one or the other part of the country. The compound effects of multiple stresses during monsoon season is reflected in terms of low productivity of *Kharif* maize, which is usually less than half compared to irrigated *Rabi* maize. Even within *Kharif* maize area there is huge variation in district-wise average productivity, ranging from less half tons to as high as 6.5 tons ha^{-1}. Analysis of the district-wise average productivity indicated that out of 514, average productivity of almost 415 districts is less than national average productivity (Zaidi et al., unpublished). Therefore, there is need to cluster districts into high, moderate and low productivity zones, identify set of yield-limiting factors and their intensity in each clusterand design cluster-wise breeding and crop management strategy to improve yields in moderate and low yielding clusters to eventually achieve overall increase in national average productivity under rainfed *Kharif* season.

Stress-resilient maize: an option for current and future climate

Simulation studies demonstrated that climate change will have a negative impact on maize yields across locations in tropics, but the degree of impact varied with region, level of warming and rainfall changes (Tasfaye et al., 2017). Combining hotter and drier climate change scenarios (involving increases in warming with a reduction in rainfall) resulted in greater simulated average maize yield reduction than only in the hotter climate change scenario. Incorporating combined drought and heat tolerance into benchmark varieties increased simulated maize yield under both baseline and future climate scenarios. While further evidence is required to document the risk-reduction benefits of climate-resilient maize on the number of chronically poor farmers, an increasing body of evidence confirms the benefits of climate-resilient maize in terms of increased yields and reduced yield variability (Cairns and Prasanna, 2018).

With increasing climate variability with high uncertainty there is urgent need to focus developing of maize hybrids that are resilient to variable weather conditions within seasons, rather than tolerance to individual stresses at a specific crop growth stage(s). Maize production can be sustained under adverse climatic conditions and further increased by using genetic diversity which harbours favourable alleles for high yield, biotic and abiotic stress tolerance (Prasanna et al., 2012). Hybrids with increased resilience to abiotic and biotic stresses can play an important role in autonomous adaptation to climate change. Targeted breeding with integration of precision phenomics, genomic-assisted selection and breeding and doubled haploid (DH) technology offer a powerful strategy to develop climate-resilient maize germplasm. However, the time-lag between the development of improved hybrid and its adoption by farmers underscores the urgency of adopting such a strategy (Cairns et al., 2012; Prasanna, 2018).

There is a myth that breeding for stress tolerance/resilience causes yield drag under optimal growing/high yield conditions. An extensive multilocation evaluation of stress-resilient hybrids along with popular commercial checks in sub-Saharan Africa (Banziger et al., 2006) and a recent study in Asia (Zaidi et al., 2020) have demonstrated that a targeted breeding approach based and selection across stressed and unstressed conditions leads to development of high-yielding stress-resilient maize hybrids without yield penalties under optimal conditions.

Developing stress-resilience maize – integrating novel tools in mainstream breeding

In active collaboration with national programs and private sector partners in the region, CIMMYT-Asia maize program has initiated several projects focusing on saving achievable yields across environments by incorporating a reasonable level of tolerance/resistance for key stresses without compromising on yields under optimal conditions. Integrating genomics and field-based precision phenomics and focusing on reducing genotype × environment interaction effects, new generation of maize germplasm was developed with multiple stress tolerance that can grow well across varied weather conditions within or across seasons. These new generation maize cultivars are being targeted at climate-vulnerable environments where they are invariably exposed to a wide range challenges, such as drought, heat, waterlogging and biotic stresses. The aim of this initiative has been to develop and deploy suitable maize germplasm for current climatic conditions and maintain a product pipeline to effectively feed the requirement of emerging challenges due to future climatic situations in the Asian tropics. This is achieved by systematic integration of the following key components:

- *Base germplasm with key traits*, i.e. constitution of the multiparent breeding population by intermating established trait donors for a set of traits for targeted environments with elite high-yielding lines with proven commercial value;
- *Integration of novel breeding tools*, including genome-wide association studies (GWAS), genomic selection (GS) and double haploid (DH) technology to fast-track the stress-resilience breeding pipeline;
- *Field-based precision phenomics* for stress-adaptive traits along with grain yield at several representative sites under managed-stress screens and
- *Partnerships* to bring together committed partners, including both public sector R & D programs and private sector seed companies in the region for sustainable

development, deployment and scaling-out of climate-resilient cultivars in stress-prone agro-ecologies.

References

ADB (2009) Climate change threatens water, food security of 1.6 billion South Asians. https://reliefweb.int/report/.

Banziger M, Setimela PS, Hodson D, Vivek B (2006) Breeding for improved abiotic stress tolerance in maize adapted to southern Africa. *Agric Water M*anag. 80:212–224.

Cairns JE, Prasanna BM (2018) Developing and deploying climate-resilient maize varieties in the developing world. *Current Opinion in Plant Biol.* 45:226-230.

Cairns JE, Sonder K, Zaidi PH, Verhulst N, Mahuku G, Babu R, Nair SK, Das B, Govaerts B, Vinayan MT, Rashid Z, Noor JJ, Devi P, San Vicente F, Prasanna BM (2012) Maize Production in a Changing Climate: Impacts, Adaptation and Mitigation Strategies. *Adv Agron*. 114:1-58.

Kashyapi A, Deepa AK, Anita SB, Archana PH (2012) Asian monsoon in a changing climate – Does it have impact on *kharif* season agriculture? International conference on "*Opportunities and Challenges in Monsoon Prediction in a Changing Climate*", 21-25 February 2012, Pune, India.

Prasanna BM (2018) Maize in Asia – Status, Challenges and Opportunities. Book of Extended Summaries, 13th Asian Maize Conference and Expert Consultation on Maize for Food, Feed, Nutrition and Environmental Security. Ludhiana, India, Oct 8-10, 2018. CIMMYT, Mexico D.F.

Tesfaye K, Zaidi PH, Gbegbelegbe S, Boeber C, Rahut DB, Seetharam K, Erenstein O, Stirling C (2017) Climate change impact and potential benefit of heat-tolerant maize in South Asia. *Theo App Climat.* 130:959–970.

Zaidi, P.H.; Thanh Nguyen, Dang N. Ha, Suriphat Thaitad, Salahuddin Ahmed, Muhammad Arshad, K.B. Koirala, T.R. Rijal, P.H. Kuchanur, A.M. Patil, S.S. Mandal, Ramesh Kumar, S.B. Singh, Bhupender Kumar, J.P. Shahi, M.B. Patel, M.K. Gumma, Kamal Pandey, Ramesh Chaurasia, Azizul Haque, K. Seetharam, Reshmi R. Das, M.T. Vinayan, Zerka Rashid, S.K. Nair[1] and B.S.Vivek (2020) Stress-resilient maize for climate-vulnerable ecologies in the Asian tropics. *Aust.J. Crop Sci.* (accepted)

VALUE CHAIN DEVELOPMENT IN MAIZE FOR HIGHER PROFITABILITY IN INDIA

K Srinivas and Ranjit Kumar
ICAR-National Academy of Agricultural Research Management, Rajendranagar
Hyderabad
ksrinivasnaarm@gmail.com

Maize is important to India as 15 million Indian farmers are engaged in Maize cultivation allocating more than 9.0 million hectares (mha) of land the crop. It is grown throughout the year. It is predominantly a kharif crop with 85 per cent of the area under cultivation in the season. Maize is the third most important cereal crop in India after rice and wheat. It accounts for around 10 per cent of total food grain production in the country. In addition to staple food for human being and quality feed for animals, maize serves as a basic raw material as an ingredient to thousands of industrial products that includes starch, oil, protein, alcoholic beverages, food sweeteners, pharmaceutical, cosmetic, film, textile, gum, package and paper industries etc. Having realized the potential of the crop in generating better income and gainful employment to the farmers, maize qualifies as a potential crop for doubling farmer's income. The consumption of maize has been increasing consistently over a period of five years (CAGR of 11%, FICCI and PWC report 2018). More than 3000 products are in market made from different parts of maize including its starch. This creates a huge market demand for maize in the world. Indian maize farmers need to capitalize this opportunity along with different stakeholders in the maize sector.

Although, India has received maize production level of 26 mt, it would require around 30 million tonnes of maize by the year 2021 (Kumar et al. 2013). However, Kumar (2013) suggests that only 13 per cent of total maize area harvested grain yield of more than 4 t/ha, while 44 per cent harvested < 2 t/ha, thus jeopardizing the profit sustainability of the growers. On the other hand, the per capita consumption of maize as food has drastically reduced in rural India from 3.7 kg/annum in 2004/05 to 2.2 kg/annum in 2011/12. The main consumer of maize is currently the feed industry (59%), followed by other industrial usage (17%), esp. for starch manufacturingand food (10%).

Feed industry with a CAGR of 6-7% globally and within India at a CAGR of 9% presents a huge opportunity for maize growers. With the largest global livestock population, India has always remained a feed starved country. Besides, the Indian poultry industry i.e. eggs and poultry meat sector, is growing at a CAGR of around 6% and 9% respectively. Keeping these factors in view, maize will continue to remain an important crop for food, feed and fodder purposes. Overall consumption of maize between 2012 to 2016 has increased with CAGR of 11% (FICCI and PWC 2018).

In addition to production and consumption, trade plays very important role in creating value in any sector. India has a big potential for export of maize as grain, feed, seed and specialty corn due to its lower price and less freight costs to the major maize (Asian) importers on account of geographical vicinity. Therefore, maize exports have escalated during the post-2000 period and grew to 4.27 Mt in 2012, due to rising demand mainly from South Asian and Gulf countries. India has emerged as one of the top 10 maize exporters in the world. The country has exported 1.05 Mt of maize to the world for the worth of 270.16 USD Millions in 2018-19. It accounted for

2.8 per cent of the world maize exports from 2.4 per cent of the total world production (TE 2010-11) (Kumar et al. 2013).

India has major opportunities in global maize trade as about half of the global maize traded is imported by 11-12 Asian nations. Currently, India exports about 4 Mt of maize mainly to the South East Asian nations like Indonesia, Nepal, Viet Nam and Malaysia. India can easily tap this market due to its price competitiveness and geographical proximity. The expected production surplus during the next 5-10 years will also help in increasing the footprints of Indian maize in the export market.

The maize sector in India faces a peculiar challenge from internal policy changes favouring its competing crops despite the fact that there is a minimum support price for maize also. This crop is not procured by the government agencies and most of the time, it is observed that the farm gate price is lesser than support price. Besides, government schemes like RKVY and NFSM coupled with National Food Security Act 2013 give high priority to improving production and productivity of fine cereals and pulses, which may have have negative impact on maize. Peri-urban agriculture, specialty corns viz. baby corn and sweet corn, hold great promise for ensuring livelihood security. Customer preference for multi-grain Atta (flour), having fortified maize as one of the constituents, may further increase its acceptability as food crop.

Maize sector is suffering from improper value chain development- from input side to marketing of final output. From input side, supply of seed, other farm inputs, mechanization for farm operations and knowledge are the main issues. According to an estimate, more than 500 private seed companies produce and sell maize seeds. Multinationals have a major share in the maize seed industry (58%) whereas share of other small and local seed companies is 40%. The major concern with small seed companies is quality. Besides lack of quality other farm inputs and inefficient farming techniques result in inferior produce. This resulted in lower maize yields compared to other maize growing nations. Rapid hybridization, cluster-based seed production, dedicated seed cold storages for maize, Public Private Partnership (PPP) in ensuring availability of quality Maize seeds are new dimensions emerged in Maize Seed industry.

In farm mechanization, both pre and post harvest, the issue is of tillage to harvesting equipment. They are not available to the farmer in time and seems to be costly to own up. Need for Maize based silage making, Maize based Skill Development Centres (SDCs) and Public Private Partnerships to promote Maize based farm machinery banks have come out as possible avenues of investment. Rationalizing usage of other critical farm inputs like fertilizers, agrochemicals and irrigation have significant contribution in bringing overall profitability from crop. Knowledge transfer (Extension) is supposed to be the states responsibility, which is almost non-functional at most of the places. Private seed suppliers give the knowledge which is essential for survival on their own seeds. Promoting PPP in extension and marketing could created win –win situation for state government, private players and Maize growers through improved transfer of technology and assured procurement of produce at remunerative prices.

Key participants in the value chain of maize are farmers. They are the primary producers of maize. It is grown in kharif, rabi & summer season. After harvesting, farmers bring grain to nearby market such as APMC's for selling to traders, some amount is kept for domestic use. Another players are village aggregators, who operate in villages. They are the famers as well as village aggregators. They are the primary base of maize marketing and are a major market outlet for the marginal and small farmers. They aggregate the maize produce at village level and take to commission agent or traders depending on the volume of tradable maize in a district. Village aggregators often act as agents for commission agents during the peak of the maize marketing season since they are located much nearer to small and marginal farmers. Hence, they are often the most reliable link between the small and marginal farmers and the commission agent. They procure maize at the farm gate on a cash basis, thereby assembling it from the many scattered small and marginal farmers. They get the price information by the commission agents through mobile phone.

In market place, commission agent acts as a middleman between farmers & traders. These are found at almost every point of the maize supply chain. He decides the price of the maize based on quality, market demand & supply & makes the selling/ buying happen. Sometimes he also provides financial help for farmers during growing season. These commission agents mainly take advantage of having information of potential buyers and sellers. He charges around 2-3 per cent commission of total produce brought for sale. Traders buys maize directly from farmers or through dealers. He decides the price based on quality (Moisture %, broken/ unbroken grains, colour etc.). He supplies to feed industry, starch industry, food industry exports etc. Brokers are middleman between traders & feed industry. He gets the order from feed industry related to supply of maize. Feed industry specifies the demand, quality parameters & price specification to brokers. He settles the contract between traders & feed industry. Feed industry engaged in manufacturing and marketing of feed to end customers through various channels such as direct to customer, through dealers or through contract farming/integration. The above signifies that state wise meticulous planning is required for productivity led growth of Indian Maize. Some of the innovative methods for better value chain efficiency in Maize sector are: using ICT for delivery of knowledge, Use of micro transport using IoTs for effective delivery of all inputs and outputs, using Artificial Intelligence and GIS platforms to predict and prevent the possible biotic and abiotic stresses. Use of the acquired data for better planning and farm management services.

Keen interest has been evinced by private sector players as well as Government in harnessing the potential offered by Maize sector. Their interest has been buoyed by expected increase in consumption of Maize. To realize the potential of maize to create value for the producers, it is necessary to have an amalgamation of strategies and interventions around technological innovations, promoting producer aggregation and linkages, enabling supporting infrastructure, forgoing PPP relationsand facilitating several policy interventions. Maize is one of the highest traded agricultural commodities on new age market system, like commodity exchanges- Spot as well as futures. Commodity market works just like any other market; it can be a physical or virtual place where commodity trading occurs. However, the commodity market is characterized by its strong regulations and rules. The trading and exchange of commodities work through legal entities, known as commodity exchanges. Commodity exchange is an association, company, or any legal corporate body which provides an organized marketplace for trading in commodities. Worldwide there are many commodity exchanges specialized in operating with certain commodities. The Chicago Board of Trade is one of the major and most known commodity exchanges operating with agricultural commodities such as corn, soybeans, wheat, oatsand rice. There are two ways how commodities can be traded: Trading in the spot market; which means that the commodities are exchanged immediately when setting a deal, either for cash or other goods. The price is set according to the current market prices and delivery occurs immediately or a few days later. Trading in the form of futures contract; which means that the buyer and seller instead of goods, exchange the contract which obligates them to buy or sell the commodity on a specific date in the future and at a particular price.

Currently, In India, maize is traded at few centres of commodity exchanges: like Patna (Bihar), Chhapra (Bihar), Begusarai (Bihar), Motihari (Bihar), Dohad (Gujrat), Banglore (Karnataka), Jhabua (Madhya Pradesh), Udaipur (Rajasthan), Bahraich (Uttar Pradesh), Kanpur (Uttar Pradesh), etc. It is also traded in the Multi Commodity Exchange of India Ltd (MCX) and National Commodity and Derivatives Exchange (NCDEX).

References

Kumar, R., K. Srinivas and N. Sivaramane (2013) Assessment of the maize situation, outlook and investment opportunities in India. Country Report – Regional Assessment Asia (MAIZE-CRP), National Academy of Agricultural Research Management, Hyderabad, India

FICCI & PWC (2018) Maize vision 2020 a knowledge Report during India Maize summit 2018.

AGRICULTURAL MARKETING SYSTEM IN INDIA: MARKETING POSSIBILITIES OF ESSENTIAL OILS-OPPORTUNITIES AND WAY FORWARD

S.R. Singh, *Deputy Director (Marketing and Skills)*
Chaudhary Charan Singh National Institute of Agricultural Marketing, Jaipur
Ministry of Agriculture & Farmers Welfare, Government of India

Current scenario

Agriculture has been the major source of livelihood generation in India and more than three-fifths of India's population draws their livelihood from agriculture that adds just one-fifth to its GDP. There should be obvious serious concerns about efficient functioning of this sector both in terms of its output /productivity and its marketing. There are several bottlenecks present agricultural marketing in India. While output and productivity are supply side factors, markets provide an intermediate link between producers and final demand source by consumers. Efficiently functioning markets add to welfare of producers as well as consumers. Interventions at different level of value chain and in domestic agricultural markets can affect the efficient allocation of resources negatively thus making domestic agricultural sector less competitive in international markets. This effect can get further magnified through interventions in the border trade policies which also affect the movement of agricultural commodities from one state to others. In India, farmers' produce is generally disposed off in the village, rural / primary market or secondary agricultural market. The number of regulated (secondary) agricultural markets are around 7,157 as of March 2014 as compared to just 286 in 1950. There are also about 22,221 rural periodical markets scattered all over country, about 15 per cent of which function under the ambit of regulation. Average area served by a market is 115 sq. km while an average area served by a regulated market is 454 sq.km (varies from 103 sq km in Punjab to 11,215 sq km in Meghalaya). According to recommendations by National Farmers Commission, availability of Markets should be within 5 km radius (approx. 80 sq km) (2004). Regulated markets are managed by Agricultural Produce Market Committees or APMCs. Regulatory barriers have constrained investments in development of storage and processing, hampered the development of effective market institutionsand lowered the capacity of agricultural producers to be internationally competitive. India, for example, is the world's largest producer of fruit and vegetables but inadequate post- harvest storage and transportation cause losses of around 30-40 per cent, only 7 per cent value addition takes placeand only about 2 per cent of production is processed commercially (Government of India, 2001). As a result a broad consensus has emerged about the need for reforms in agricultural market policies and quite significant reforms have been implemented in recent years, as part of the ongoing policy reform process in India.

Linking small primary producers with markets has been identified as one of the major issues in policy and practice in improving livelihoods for millions of poor in the developing world. Small producers have many competitive advantages like lower cost because of family labour abundance, higher capability in working capabilityand traditional knowledge that can be harnessed for many sectors.

The only threats they face are: the demand for standardized products in global and national markets. But there are opportunities in organic, fair and ethical trade markets that are particularly suited for small producers and offer higher prices. On the other hand, private agencies also stand to gain from small-producer linkages when the focus is not just on profits, private agencies can leverage this smallholder linkage by way of political and social legitimacy. Besides, dealing with small producers can lower costs as compared to dealing with larger onesand smaller producers are generally easier to manage. Typically, farmers complain a lack of market for their produce, while processors, exporters or supermarket retailers complain of a lack of adequate supplies of quality produce.

This marketing paradox is present because often, buyers do not reach out to explore new suppliers or farmers lack an understanding of markets as well as the ability to identify mew markets or to take advantage of such opportunity with value addition activities like grading, cleaning, sorting, packaging and primary processing.

Globallyand more so, in the developing world, including India, in numerous types of market linkage arrangements, success depends on the market and the efficiency of operations. Some offer higher price opportunities for growers, while others offer lower marketing costs, thus increasing producer profit margins either way. But, most of these arrangements, especially indirect ones, do not ensure that small growers are part of these arrangements. Many market linkage arrangements just provide another alternative to the primary sellers without any commitment to buy or add value as is the case with most fresh F&V retail chains in India which procure only 'A Grade' produce without any contract and the producer is left to sell the rest of the produce in other channels. Most of these channels also deal with individual growers and there have just been only few attempts by private corporate players encouraging the formation of grower groups or associations through the producer company route in India.

Major issues and concerns

- Too many intermediaries resulting in high cost of goods and services and they extract major share in consumers rupees.
- Inadequate infrastructure for storage, sorting, grading or post-harvest management resulting huge wastage of fruits and vegetables as well grains.
- Private sector unwilling to invest in logistics or infrastructure under prevailing conditions
- Price setting and discovery mechanism not transparent
- Mandi staff ill-equipped and untrained
- Market information not easily accessible and ambiguous
- Movement of agri-produce from one place to another is difficult due State Act.

Condition of existing market

- Primary or Periodic Markets (*haat / bazaars*) are most neglected – basic amenities not available
- Condition of cattle markets most appalling
- Low density of regulated markets in some States- farmers have to travel long distances
- Weak governance of APMCs - management not professional
- Licensing systems creates entry barrier to new trader / buyers
- Multi-Point Levy of Market Fee (Varies from 0.5 to 2%) and Multiple Licensing System
- Restrictions on movement of goods inter-state and even intra-state

Gaps in marketing infrastructure

- NHM- only 11 States have taken initiative in establishing 109 cold storages and eight states have established 51 apni mandis, there is virtually no progress in the setting up of wholesale markets except in Kerala
- Only 1637 grading units at the primary level, which include 125 units with cooperatives and 144 units with others
- Regulated markets, there are only 1368 grading units in a total of 7246 market yards/sub-yards.
- Only around seven percent of the total quantity sold by farmers is graded before sale
- Scientific storage capacity is only 30 per cent of the required capacity.
- Cold storage facility is available for only 10 per cent of fruits and vegetables

Need for reform in agricultural marketing

- Empower producers with knowledge, information & capability to undertake market-driven production.
- Provide Multiple Choice and competitive Marketing Channels to farmers.
- Attract Large Scale investments needed for building Post-Harvest infrastructure.

Linking small farmers to the market

Strategies on the following principles to extend help to smallholder agriculture and disadvantaged producer groups. The Plan:

- aim to improve the terms of trade of small producers with the market
- address risks faced by small producers and help to reduce them
- recognize the importance of small producers in the value chain and facilitate their inclusion in the wider economy target the moving small producers further up the value chain to increase their returns on investment and their economic security.

Alternative marketing models

An analysis of various alternative models

India has made many strides on production front but awfully lacking in the field of agricultural marketing. These inadequacies are becoming more acute with the significant changes taking place in agri-food systems in domestic and overseas markets; the attainment of competitiveness is becoming increasingly dependant on the capacity of the country to develop effective and efficient agricultural marketing. Presently agricultural marketing system in India suffers from number of constraints which are either infrastructure related or government regulation related or technology related or related to poor information on domestic and overseas markets and opportunities or related to unstable and uncertain produce prices or related to delayed and late payment to producers and finally related to low producer's realization.

The existing marketing infrastructure in the form of Rural Primary Markets, regulated wholesale and assembling markets, grading and quality control systems, retail markets, storage including cold chain infrastructure, infrastructure required for linking the commodity futures with the farmers, perishable cargo centres, rural farm road infrastructure, market information infrastructure, infrastructure for livestock markets, poultry and livestock meat markets, slaughter house facilities and quality assurance infrastructure of various agricultural commodities is far below the desired / required levels both in terms of capacity as well as quality of the facilities. This infrastructure is also inadequate to realize the potential competitiveness of multiple commodities for taking them to the global markets.

Alternate marketing systems: Indian producers are unable to realize optimal value from their produce and progress further due to fragmentation of land holdings and lack of grass-root level organizations. On the other hand, processors are not in a position to get quality raw material in right quantity.

Besides the share of producer in consumer price is abysmally low due to the presence of middlemen. To overcome these problems, direct marketing, contract farming, direct linkage with Retailers/ Processors/ Exporters and market oriented production are some of the approaches. Recently many initiatives have been taken by NABARD, NIAM and other organizations to promote and involve Self Help Groups, Joint Liability Groups, Farmer clubs, Farmer Federations, SHG Federations, Producer organizations such as Producer Companies, Producer cooperatives, etc in direct marketing of the farmers' produce for better price realization.

Government initiatives: To promote direct interactions of producers with consumers in fresh produce, there have been farmers' markets in India in the form of *Apni Mandis* in Punjab, *Rythu Bazaars* in Andhra Pradesh, *Uzhavar Santhai* in Tamil Naduand *Shetkari Bazaar* in Maharashtra, promoted by state agencies. Farmers' markets have helped participating farmers to become aware of the products required by the markets and helped farmers to improve product quality and diversify their product portfolios, besides bringing about resource use maximization. However, farmers' markets have not had a major impact on farm incomes as sales through this marketing channel are generally small, both in terms of number of the farmers participating and volumes of produce. The more significant govt. initiatives include Horticultural Producers' Coop. Marketing & Processing Society (HOPCOMS – a cooperative) in Karnataka and SAFAL F&V project of National Dairy Development Board (NDDB) in Bangalore.

Producer Groups / Farmer Groups (PG / FG) – Producers' Associations (PAs) – Farmer Common Service Centers (FCSCs): Group Activity is more effective for the benefit of the members of the group than the individual efforts. Informally formed small groups called as self help groups have exhibited their strengths in various fields including agriculture, in improving financial conditions of the members. Farmer Common Service Centers (FCSCs) are conceptually small scale commercially viable entities owned by Producers' Associations (PAs).

The FCSCs will support 250-300 members, through Producer Groups / Farmer Groups of around 12-19 active members in each Producer Groups (PGs).

The following options could be available to the members of the PAs after using the services provided by the FCSCs:

(i) Take their produce to a State Agencies Warehouse or to APMC warehouse or sell in APMC.

(ii) Obtain finance against their produce through the Warehouse Receipt Financing from banks for the produce store in the State Warehouse or other accredited warehouses.

(iii)They can sell the produce on spot or future market depending on price situation known through the warehouses.

(iv) The produce can be sold to direct marketing license holder who may be a trader, exporter, processor or retail chain operator.

An estimate of the potential additional returns that farmers can obtain by using the FCSC for their producer association to grade, clean and pack grain and to facilitate marketing through the Mandi, the Spot Market at a warehouse facility, or to store at warehouse for three month contrasted with the returns for a farmer selling un-graded produce through the Mandi shortly after harvest shows higher returns to the farmers as 5%, 10% & 15% respectively.

E-Trading: The concept of E-trading or 'Virtual Market' is innovative and experimental. Virtual Markets for agricultural products are very much in their infancy but with new technological development, field results are undergoing significant revision and refinement. Various states have amended the APMC Act on the lines of the Model Act and the Rules under the Act provides for e-trading. States have already granted licenses to MCX and NCDEX for carrying out e-trading activity. The e-trading system would enable producers, user organizations, electronic traders and existing traders to be able to offer product to the market and that a system would be in place that would enable buyers and sellers to broadcast buying needs and product requirements to one another.

Direct marketing: Farmers' Markets were introduced with a view to eliminate the middlemen and arrange facilities for the farmers to sell their produce directly to the consumers at reasonable rates fixed every day. On account of the scheme, both the farmers and the consumers are benefited. Some examples of these channels are *Apni Mandi*, *Rythu Bazars*and *Uzhavar Sandies*. These channels are mostly adopted in sales transactions of agricultural commodities like fruits, vegetables and flowers which are highly perishable. In this channel, the produce move quickly from farmers to consumers due to absence of middlemen.

Keys to inclusion of smallholder farmers in dynamic markets

1. **Organized retailing:** To be promoted by removing all restrictions on FDI for creating good competition for domestic players and to bring new technologies and management practices provided commodities are procured only from Producers Organizations.

2. **Market Access for small producers:** The market access depends on: (a) understanding the markets, (b) organizing of the firm or operations, (c) the existence of communication and transport linksand, (d) an appropriate policy environment. Understanding the markets in a modern context involves understanding the value chains and networks and their dynamics from a small producer perspective. Interventions like Farmer Common Service Centers could be an appropriate forum for such a market access.

3. **Reforms for efficient traditional markets:** The functioning of traditional markets (APMCs) needs to be improved to enhance their cost efficiency so that producers and consumers can realise better prices. The amended APMC Act allows for the setting up of private markets. It is also necessary to enforce an open auction system, improve buyer competition in markets, provide better facilities such as cold storageand improve farmers' access to market information. These markets are important to small farmers and even a significant proportion of medium and large farmers, who still

depend on them; they also serve as main competitors to contract farming and can improve the terms offered to contract growers.

4. **Integrated value chain promotion**: There is a need to combine value chain promotion with livelihood perspective to enable the resource poor to enter in to and stay in to globalized commercial markets. Innovation in smallholder market linkage are needed in terms of partnership, use of information and communication technologies, leveraging networks, value chain financing, smallholder policyand, even in contracts that can promote both efficiency and inclusiveness of the linkage.

5. **Promotion of innovative marketing models**: Choosing the right market and a market development strategy is essential to scale up the operations that can come only by innovation of products and business models. It is not market access but effective market participation that is at the heart of success of any market linkage for primary producers.

6. **PPP for efficiency and effectiveness**: Partnership with the private sector can come in handy as they can provide technologyand upgrade business (quality) and social standards. For this, POs and their staff and farmers should be more market-oriented and have the capacity to work with and negotiate fair contracts with private agencies. This requires training of PO personnel and farmers in modern markets and their dynamics which includes contract negotiation, business management, market research, supply or value chain analysis, basic business documentation and crop and farm plans and budgets.

RECENT ADVANCES IN CONSERVATION AGRICULTURE MACHINERY FOR SUSTAINABLE AGRICULTURE

Harminder Singh Sidhu
Sr. Research Engineer, Borlaug Institute for South Asia, Ludhiana
H.Sidhu@cgiar.org

Conservation Agriculture (CA) practices with increased acceptance across the globe are now considered as harbinger for agriculture sustainability and productivity. Its positive impact on natural resourcesand adaptation to and mitigation of climate change effects are widely acknowledged. CA based crop management technologies are "open" approachand easy to mainstream. In South Asia, CA is a relatively new introduction compared to developed world. CA will be able to quickly address two critical concerns faced by South Asian agriculture today- low farm economics and degrading natural resources. Availability of machinery suited to local conditions is generally a major limitation in adopting CA in Asia and Africa. Capacity development of researchers on CA machinery is also vital for development, adaptation and up scaling of CA for realizing its impact in the region. Keeping the emerging challenges before the South Asian farmers, there is a need for a collective movement on CA in general and developing suitable multi-crop CA machinery in the region. In the past for more than a decade considerable efforts are being made for developing suitable machinery suited to different cropping systems under CA. The brief description of important CA machinery/technologies developed in India is given below:

1. **Laser land leveller**: Water is the most important resource on the earth. However, availability of water is limited in many parts of South Asia, particularly in north-western (NW) India. There is therefore, an urgent need for judicious use of our limited water resources. The enhancement of water application efficiency at field level is one of the best options to redress the problem declining of water level in the state. Precision land levelling (PLL) is the foremost step in this direction which could assist in efficient utilization of water. Results have indicated that PLL saves water to the tune of 20-25% and irrigation time by 30% and also improves crop productivity by 10-15%. This technology will not only conserve water and save electricity but will also improve the judicious use of other agricultural inputs like fertilizer, insecticides, pesticides and weedicides etc. This also results in uniform maturity of the cropand better quality and higher yield. Moreover, PLL is a precursor for adopting other resource conservation technologies. At present more than 35000 laser levelling machines are working in India. The demand of this technology is still increasing in the states like UP, Rajsthan, Gujarat and Andhra Pradesh, after the successful large scale adoption in Punjab and Haryana. The introduction of Auto Survey laser land leveller is another milestone in the development of CA machinery (Sidhu et al., 2019). This unit is capable of surveying the field automatically and instruct the hydraulic directional control valve to set the drag bucket at the desired mean level without any manual intervention. The detail testing of this machine showed that the average field capacity and the land uniformity index of the automatic laser leveller was 13 % and 12 % more respectively, with 11 % less fuel consumption than manual laser land leveller. This machine is now being commercially sold to the farmers.

2. **Multi-crop planter:** The rice-wheat , cotton-wheat and Maize –wheat are the major crop rotation of in the NW India. All the operations in wheat are almost mechanized while rice transplanting is totally manual making this system highly energy intensive. The shortages of water and labour are the driving forces for re-evaluation of rice establishment methods. A shift in rice production system from transplanted rice to dry direct seeding of rice (DSR) is testimony of the resource conservation technologies (Gupta *et al*., 2006). The uncertainty in the availability of water/electricity early in the season, is another reason for adoption of DSR in timely planting of rice in Punjab & other parts of India.

2.1 Functional requirements of direct seeded rice planter:

The machine should able to maintain optimum plant to plant and row to row distance without any mechanical seed injury using a seed rate of 15-20 kg/ha at desired seeding depth between 2-5 cm.

2.2 Machines with inclined plate metering mechanism:

The machines/planters with multi-crop inclined plate metering mechanism are more suitable for seeding rice (see the figure on right hand side)). These machines are capable of maintaining seed to seed and row to spacing with very low injury to the seeds. The chances of missing due to machine vibration are also very less compared to other systems. These planters can also be used for planting other crops like maize, cotton, groundnut etc by simply changing the inclined plates designed for a specific crop and adjusting row to row spacing. Till date the inclined plate seed metering is the best to meet all the functional requirements of the multi crop planting machines. The cost of the machine is Rs75000/- with working width 1.8 m and field capacity is 0.4 ha/hr. But an additional inclined plate metering box costing only Rs. 20000/- can also be attached to the existing zero till drill/ Happy seeders as an alternative to buy a separate machine.

3. **Relay Seeding in to standing Crop:** In South Asia, cotton-wheat (CW) rotation (~4.5 M ha) is one of the potential candidate for major gains in future wheat production of the region. In the CW system, wheat planting after cotton harvest is often delayed (by 20-44 days) due to late picking of cotton and subsequent tillage and field preparation operations needed for conventional wheat planting. This leads on average > 0.5 t ha^{-1} lower wheat productivity planted after cotton compared to that after rice. Therefore, timeliness in wheat planting under CW system warrants a new innovation to overcome the problem of delayed wheat planting. A two-wheel self-propelled relay seeder was developed in 2009 by the Cereal Systems Initiative for South Asia (CSISA)/

Relay Seeding of moong into paired row wheat

CIMMYT team in collaboration with Amar Agro Industries, Ludhiana, India (Buttar et al., 2013). The prototype is capable of direct drilling of wheat along with basal fertilizers in three rows (18 cm spacing) between two rows of standing cotton (67.5 cm apart). Results of the farmers' participatory field trials revealed that relay seeding of wheat using innovative relay seeder resulted in the yield gains of more than 0.5 t ha^{-1} due to advancing sowing of wheat by 20-44 days compared conventional sowing.. However, farmers of CW belt in Punjab showed little interest in adoption of two-wheel tractor driven relay seeder due to their large size farm holdings. Keeping this in view, efforts have been made to develop high clearance platform for 4-wheel tractor which can be used in the standing cotton. A prototype of tractor operated relay seeder has also been developed and being evaluated by Borlaug Institute for South Asia (BISA), Ludhiana in collaboration with machinery manufacturer and Department of Farm Machinery & Power, PAU, Ludhiana. The efforts have also been made to seed moong bean in to the standing wheat to advance the seeding of mung bean by 20-25 days to get the assured yield of moong without facing the challenge of advance monsoon.

4. High Clearance Tractor and Sprayer: Mechanized weeding and spraying in most of the row crop including maize is not possible after certain crop height. The limitation was the ground clearance of tractor and boom sprayers. To address this challenge high clearance tractor (mentioned in above section) was used to operate a high clearance sprayer. The high clearance sprayer is a simple modification of a normal boom sprayer by changing the position of the square axil for tyres. It only takes 1 hour to convert a normal sprayer to a high clearance sprayer. With this modification ground clearance of the tractor & sprayer has increased from 40 cm to 80 cm which will facilitate the easy movement of the machines in the standing crop even at the late stage with any injury or damage to the crop. Below are the pictures showing tractor and boom sprayers at the normal and high clearance height.

5.Super SMS for Combine Harvesters: The manual spreading of loose straw in a combine harvested field takes 8-13 man-h/ha and it is very difficult to spread the entangled dry loose straw due to its light weight. Keeping this in mind, a straw management system (SMS) and now known as super SMS was developed which can be used as an attachment to the existing conventional combine harvester for managing and evenly spreading the loose straw in the harvested area. This will not only facilitate the smooth operation of Happy Seeder in combine harvested fields but also will help in conserving moisture in the field after harvesting which in turns is very helpful in widening the seeding window of wheat in the residual moisture.

6. The Happy Seeder: Rice straw has no economic use with the farmers and industry and thus remains unutilized in combine harvested rice fields in NW India. In order to seed wheat on time, the majority of the farmer's burn rice straw in-situ in NW India as it is an easy and cheap option causing intense air pollution and losses of plant nutrients. Rice straw incorporation is practiced by less than 1 % farmers as it is energy and time intensive and delays wheat sowing. Developing a cost-effective technique for better utilization of this vast resource was an important challenge for the farm engineers. Happy Seeder (HS) was developed to sow wheat into rice residue without burning. The HS cuts and manages the standing stubble and loose straw in front of the furrow openers, retaining it as surface mulch and sows wheat in a single operational pass of the field. Operational costs for sowing wheat are 50-60% lower with HS than with conventional sowing. (Sidhu et al. 2015) The introduction of energy efficient blades and triple action straw management rotor in HS further reduced the operational power requirement by 20-25 % and improved the field capacity by 15 %. However, evenly spread loose straw is a precondition for the smooth operation of all second generation drills including the HS. At present more than 15,000 machines are operational in the region in last 2 years. The happy seeder can be used to sow other crops like moongbean, maize , soybean, chickpea and rice in the presence of residue by making some simple adjustment/attachments in the exiting machine. Future research should also focus on the improvement in method of irrigation & fertilizer application (eg. fertigation) to further improve input use efficiency in CA-based different cropping systems.

7. Layering conservation agriculture and precision water and nutrient management using sub surface drip (SSD) irrigation system: Adoption of drip irrigation for suitable crops (vegetables & horticulture) has shown tremendous reduction in crop water requirements ((Sharma et al., 2009). However, there have been very limited efforts on drip irrigation major water consuming field crops (like rice, wheat, maize etc) across the world. The biggest bottle neck in adoption of surface drip irrigation in cereal based systems is labour use in frequent shifting of drip lines for different operations during crop growth. BISA-CIMMYT at Ludhiana, India have initiated a new research on precision-conservation agriculture in rice-wheat and maize-wheat systems. A new machine for laying sub surface drip lines has been developed at BISA, Ludhiana, which is highly economical and labour efficient. The results of first of its kind research on layering sub-surface drip with conservation agriculture based rice-wheat and maize-wheat rotations have shown tremendous potential to dramatically cut irrigation water use while producing more compared with conventional system of flood irrigation. It has been observed that irrigation water productivity increased by about 150 and 100% in maize and wheat, respectively. In addition there was a 25% saving of fertilized N under fertigation in both maize and wheat without any yield penalty. In rice the saving of 20% fertilizer N and increased irrigation water productivity by about 60% has been observed with similar yields.

In conclusion there is a need for more research to develop appropriate mechanization strategies as a collective movement on CA for different agronomic management (weeding and fertilizer placement in standing crop) in the region. For accelerating the pace of adoption of CA & diversification in the region, development & evaluation of multi-crop, multi-utility machines for CA and human resource development need immediate action as ***"Un-sustainability cannot be an option in the modern agriculture"***.

References

Buttar GS, Sidhu HS, Singh V, Jat ML, Gupta R, Singh Y and Singh B (2013) Relay planting of wheat in cotton: an innovative technology for enhancing productivity and profitability of wheat in cotton–wheat production system of South Asia. *Exptl Agric* 49:19-30.

Gupta R, Jat ML, Singh S, Singh VP and Sharma RK (2006). Resource conservation technologies for rice production. *Indian Fmg.*56 (7) 42-45.

Sharma BR, Amarasinghe U and Xueliang C (2009). Assessing and Improving Water Productivity in Conservation Agriculture Systems in the Indus-Gangetic Basin. Lead paper for the "4th World Congress on Conservation Agriculture-Innovations for Improving efficiency, Equity and Environment, Irrigated Systems, National (Indian) Academy of Agricultural Sciences, NASC Complex, Pusa, New Delhi, India; 4-7 February 2009.

Sidhu HS, Singh M, Singh Y, Blackwell J, Lohan SK, Humphreys E, Jat ML, Singh V and Singh S (2015). Development and evaluation of the Turbo Happy Seeder for sowing wheat into heavy rice residues in NW India. *Field Crops Res.* 184: 201-212.

Sidhu HS, Singh M, Singh Y, Singh SK and Pandey HS (2019). Performance evaluation of automatic vis-à-vis manual topographic survey for precision land levelling. *Precision Agri*. (in press).

VITAMIN-A ENRICHMENT IN MAIZE: STATUS AND PROSPECTS

Firoz Hossain[1*], Vignesh Muthusamy[1], Rajkumar U. Zunjare[1], Hriipulou Duo[1], Rajat Goswami[1], Manoj Gowda[1], Brijesh K. Mehta[1], Abhijit Das[1], Bhukya Prakash[2], Bhupender Kumar[3], John Joel[4], Rajesh Khulbe[5], Mehar C. Kamboj[6] and Sujay Rakshit[3]

[1]ICAR-Indian Agricultural Research Institute, New Delhi
[2]ICAR-Directorate of Poultry Research, Hyderabad
[3]ICAR-Indian Institute of Maize Research, Ludhiana
[4]Tamil Nadu Agricultural University, Coimbatore
[5]ICAR-Vivekananda Parvatiya Krishi Anusandhan Sansthan, Almora
[6]Chaudhary Charan Singh Haryana Agricultural University, Hisar
fh_gpb@yahoo.com

Green revolution has led to mammoth increase in grain production. Despite grain sufficiency, vast majority of people, around 815 million continues to subsist under malnourished condition. Major health problems in developing countries arise mainly due to micronutrient malnutrition, which affects nearly two billion people worldwide (Global Nutrition Report 2017). It occurs primarily due to consumption of imbalanced diet particularly deficient in essential vitamins and minerals. These deficiencies mainly affect children and pregnant women; and have profound health effects in humans affecting their growth and development leading to considerable socio-economic losses (Hossain et al. 2019). It is mainly prevalent in the developing countries like India, due to the predominance of consumption of cereal based diet (Gupta et al. 2019). Studies reported that every year India loses over $12 billion of gross domestic product (GDP) due to deficiency of vitamins and minerals (www.harvestplus.org). Among different micronutrients, deficiency of vitamin-A (VAD) is common and highly prevalent in humans (Giuliano 2014).

Significance of vitamin-A in humans

Vitamin-A is the group of organic compounds required for visual system, growth and development, immune system, maintenance of epithelial cell integrity and reproduction (Sommer and West 1996). Vitamin-A needs to be essentially supplied through diet by supplementation or balanced diet, as it can't be synthesized inside the human body. Human body said to be deficient in vitamin-A when retinol reserve is <0.1 μmol/g (Tanumihardjo 2011). Vitamin-A deficiency (VAD) affects at least 190 million pre-school children and 19 million pregnant women worldwide causing eyesight damage that leads to night blindness (WHO 2009). VAD is prevalent in Africa and South Asia, where people depend on cereals for their dietary requirement. India stands in world map with severe form of VAD (www.harvestplus.org). The daily requirement of vitamin-A in non-pregnant and non-lactating women is 500 μg/g, while it is 275 μg/g per day in case of children of 4-6 years age (Andersson et al. 2017). It also causes a keratomalacia an inflammation that causes irreversible blindness and it also causes diarrhoea and respiratory diseases (Sommer and Davidson 2002; Mayer et al. 2008; Bouis and Saltzman 2017). VAD causes many disorders like growth retardation, impaired iron mobilization, depressed immune responseand increased susceptibility to infectious diseases (Sommer and Davidson 2002; WHO 2009).

Strategies to overcome VAD

Though, diverse measures like diet diversification, food fortification and supplementation have been made to overcome the micronutrient deficiencies, limited success is achieved due to several physical and economic factors like non-availability, non-accessibility and non-affordability. On the other hand, targeting the staple crops to improve the content of these micronutrients through genetic means, often referred to as 'biofortification' can overcome these three major limitations and stands sustainable and cost-effective (Menkir et al. 2017; Bouis 2018).

Maize and its significance

Maize is the third most important staple food crop in the world, which accounts for 15-56% of total daily calories of humans in developing countries (FAS/USDA 2019). Of the maize produced in the country, 64% is used for feed, 16% for food, 19% for industrial use and 1% for others (AICRP Maize Progress Report 2017-18). Although maize is a major staple crop, the available maize varieties do not provide sufficient levels of vitamin-A to meet the recommended dietary allowance (RDA) (Gupta et al. 2019; Hossain et al. 2019). Normal maize other than white corn genotypes, possess considerable concentration of carotenoids in the grains when compared to rice, wheat and other staple cereals; but it is predominated by non-provitamin-A type of carotenoidsand has only 0.25-2.50 µg/g of provitamin-A carotenoids (Vignesh et al. 2012; Pixley et al. 2013; Muthusamy et al. 2015a). This is well below the RDA of 15 µg/g recommended for humans (Pixley et al. 2013).

Genes governing higher provitamin-A accumulation in maize

Global research efforts have led to identification of two key genes in the carotenoid biosynthesis pathway i.e., *β-carotene hydroxylase* (*crtRB1*) and *lycopene-ε-cyclase* (*lcyE*) in maize; mutant alleles of which could increase β-carotene and β-cryptoxanthin (major provitamin-A carotenoids) (Harjes et al. 2008; Yan et al. 2010). However, favourable alleles of these genes causing provitamin-A enhancement are less frequent in the population (3.38% for *lcyE*, 3.90% for *crtRB1*and 1.30% with both the alleles) (Muthusamy et al. 2015b). For both the *crtRB1* and *lcyE* genes, polymerase chain reaction (PCR) based co-dominant and gene-based markers were developed and validated (Harjes et al. 2008; Yan et al. 2010; Babu et al. 2013, Zunjare et al. 2018a). These markers have greatly reduced the intensive large scale phenotyping in the breeding populations for development of provitamin-A rich biofortified maize (Babu et al. 2013; Muthusamy et al. 2014; Zunjare et al. 2017; Zunjare et al. 2018b; Goswami et al. 2019; Sagare et al. 2019).

Global scenario of development of provitamin-A enriched maize cultivars

HarvestPlus, a CGIAR initiative on development of micronutrient dense crops has made efforts in development and release of several biofortified varieties in various crops in collaboration with the other crop based CGIAR institutions like CIMMYT and IITA. About 11 provitamin-A-rich hybrids and/or open pollinated varieties (OPVs) developed by CIMMYT, Mexico, were released in African countries like Malawi, Zambia and Zimbabwe. Around 15 provitamin-A-rich OPVs, developed by International Institute of Tropical Agriculture (IITA), Ibadan, were released in Nigeria, Ghana and DR Congo (www.harvestplus.org). Of them, three hybrids *viz*., GV662A, GV664A and GV665A were from Zambia, two hybrids (Ife maize hyb-3 & Ife maize hyb-4) and two synthetics (Sammaz 38 and Sammaz 39) were from Nigeria. One provitamin-A rich synthetic has also been released from

Ghana (CSIR-CRI Honampa). So far, more than 40 provitamin-A rich maize cultivars including synthetics, single-cross hybridsand three-way hybrids have been released in many African countries such as DR Congo, Ghana, Malawi, Mali, Nigeria, Rwanda, Tanzania, Zambiaand Zimbabwe (Andersson et al. 2017). All these hybrids/OPVs are reported to contain 6-8 µg/g of provitamin-A (Dhliwayo 2014; Simpungwe et al. 2017). Around 460 tonnes of certified seeds of provitamin-A-rich cultivars were produced for their cultivation by farmers (www.harvestplus.org). Besides, 64 synthetics and 74 provitamin-A enriched hybrids were under extensive testing in 14 African countries (Manjeru et al. 2017).

Research efforts at CIMMYT and other institutions worldwide has also led to the development of provitamin-A rich maize genotypes through exploitation of either or both of the two key genes *viz*., *crtRB1* and *lcyE* that cause higher accumulation of provitamin-A in maize kernel (Azmach et al. 2013; Liu et al. 2015; Gebremeskel et al. 2017; Menkir et al. 2017; Manjeru et al. 2017; Simpungwe et al. 2017). Using marker-assisted selection (MAS), favourable allele of *crtRB1* was introgressed in two promising inbreds *viz*., CML161 and CML171. The provitamin-A level enhanced up to 5.25 µg/g from 1.60 µg/g in CML161; and 8.14 µg/g from 1.80 µg/g in CML171 (Liu et al. 2015).

National status of development of provitamin-A enriched maize cultivars

Intensive efforts at ICAR-Indian Agricultural Research Institute, New Delhi led to development of provitamin-A rich maize hybrids (Table 1). The favourable allele of *crtRB1* gene was introgressed into parental inbreds of Vivek QPM9, Vivek Hybrid27, HM4 and HM8 using MAS; and the improved hybrids showed 5.5-10.2 fold increase in provitamin-A when compared to the original hybrids (Muthusamy et al. 2014). This has led to the release of 'Pusa Vivek QPM9 Improved' (APQH9), the first commercial hybrid in the country with high provitamin-A coupled with lysine and tryptophan (Yadava et al. 2018; Hossain et al. 2019; Gupta at al. 2019). One more hybrid 'Pusa Vivek Hybrid27 Improved' has also been released for commercial cultivation in the country during year 2020. Goswami et al. (2019) has also introgressed the favourable allele of *crtRB1* into HKI1128Q, a medium maturing elite QPM inbred and female parent of the hybrid HM9. Recently, Zunjare et al. (2018b) introgressed both *lcyE*- and *crtRB1*-favourable alleles of genes into elite *opaque2*-based parental inbreds of the four popular QPM hybrids *viz*., HQPM1, HQPM4, HQPM5 and HQPM7. 'Pusa HQPM5 Improved' and 'Pusa HQPM7 Improved' have now been released across the country and Peninsular Zone, respectively during year 2020.

Table 1: Provitamin-A-rich maize hybrids developed and released in the country

S. No.	Name of the hybrid	Maturity	Zone of release	Year of release
1.	Pusa Vivek QPM9 Improved	Early	Northern Hill Zone and Peninsular Zone	2017
2.	Pusa Vivek Hybrid27 Improved	Early	North Eastern Plain Zone	2020
3.	Pusa HQPM5 Improved	medium to late	Across the country	2020
4.	Pusa HQPM7 Improved	Late	Peninsular Zone	2020

However, number of inbreds rich in provitamin-A is very limited (10-12). In order to develop diverse provitamin-A rich inbreds and hybrids, 10 elite normal maize inbreds (1-2 µg/g of provitamin-A and good combiners for grain yield) were crossed with HarvestPlus donor inbred, HP704-22 (15-20 µg/g of provitamin-A, but poor adaptation in Indian conditions). F_2 populations of the 10 crosses were genotyped using *crtRB1*-specific *InDel* marker. Segregants homozygous for *crtRB1* mutant allele were selected (Figure 1). F_3 families were evaluated for their plant-, ear-, grain- characteristics (Figure 2).

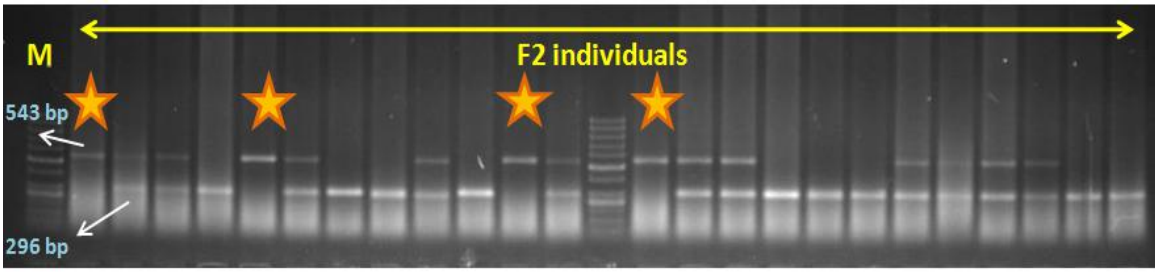


Figure 1: Segregation of *crtRB1* alleles (543 bp and 296 bp) in F_2 populations. 543 bp allele is favourable, star indicates homozygous individuals with 543 bp allele.

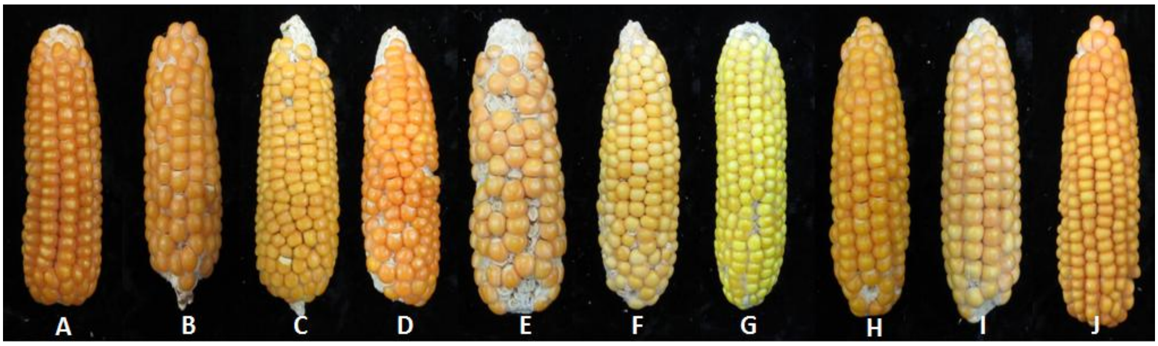


Figure 2: Ear- and grain- characteristics of selected newly derived provitamin-A rich lines (A-J)

Figure 3: Ear and grain characteristics of newly developed *crtRB1*-based hybrids

A set of selected inbreds possessing favourable allele of *crtRB1* were analyzed for different carotenoid fractions. Provitamin-A among inbreds varied from 8.33-14.63 µg/g, with an average of 11.01 µg/g. In case of *crtRB1*-based inbred lines, the contribution of β-carotene towards total kernel carotenoids was found to be 28%, while β-cryptoxanthin, lutein and zeaxanthin contributed 15%, 39% and 19%, respectively. In case of the two elite check inbreds (normal inbreds) used in the study, the contribution of β-carotene to total carotenoids was only 6%. The contribution of β-cryptoxanthin, lutein and zeaxanthin were 3%, 58% and 32%, respectively. Using some of the promising *crtRB1*-based inbreds, a set of hybrids were developedand provitamin-A varied from 7.51-14.90 µg/g with an average of 10.37 µg/g. The mean concentration for provitamin-A among check hybrids (normal maize) was 3.13 µg/g. Two promising provitamin-A rich hybrids *viz*., MGUH-15 and MGUH-24 have been identified (Duo 2019) (Figure 3).

Evaluation of provitamin-A rich hybrids for bioaccessibility studies

Grains of provitamin-A rich hybrids were analyzed for bioaccessibility studies using *Caco2* cell assay (Dube et al. 2018). The consumption of 200 g per day of biofortified maize would contribute to 52 and 64% of RDAs for adult Indian men, after adjusting for cooking losses and conversion factors. Lutein and zeaxanthin content in the maize digesta and micellar fraction was inversely related to the β-carotene micellarization and intestinal cell uptake, respectively. These results together suggest that the enrichment of provitamin-A carotenoids together with decreasing the oxygenated carotenoid metabolites such as lutein and zeaxanthin will further improve the bioavailability of β-carotene from maize hybrids.

Evaluation of provitamin-A rich grains as poultry diet

An experiment was undertaken to study the effects of provitamin-A rich maize grains on '*Vanaraja'* (poultry breed) at ICAR-Directorate of Poultry Research, Hyderabad. The provitamin-A rich grains of 'Pusa Vivek QPM9 Improved' was compared with traditional maize. It was concluded that the birds fed with the biofortified grains showed a better body weight gain and improved feed efficiency than diet made from traditional maize. Further, it considerably reduced the abdominal fat and increased breast muscle, which is highly desirable attribute of chicken meat. Further, recent international studies suggest the higher accumulation of provitamin-A in egg yolks when fed with provitamin-A rich maize grains in comparison to the traditional yellow maize available in the market.

Future prospects

Research efforts are required to study the retention of the enriched provitamin-A carotenoids in maize. Also, efforts to combine multi-nutritional traits like vitamin-E, iron and zinc to the existing provitamin-A rich cultivars would lead to development of maize genotypes that would help in alleviating micronutrient deficiencies in a holistic manner.

References

AICRP-Maize Progress Report (2018) ICAR-Indian Institute of Maize Research, PAU Campus, Ludhiana, pp. 1-10.

Andersson MS, Saltzman A, Virk PS and Pfeiffer WH. (2017) Progress update: crop development of biofortified staple food crops under HarvestPlus. *African Journal of Food, Agriculture, Nutrition and Development* 17:11905-11935.

Azmach G, Gedil M, Menkir A and Spillane C (2013) Marker-trait association analysis of functional gene markers for provitamin A levels across diverse tropical yellow maize inbred lines. *BMC Plant Biology* 13: 227.

Babu R, Rojas NP, Gao S, Yan J and Pixley K (2013) Validation of the effects of molecular marker polymorphisms in *LcyE* and *CrtRB1* on provitaminA concentrations for 26 tropical maize populations. *Theoretical and Applied Genetics* 126:389-399.

Bouis H (2018). Reducing mineral and vitamin deficiencies through biofortification: Progress under HarvestPlus. *World Review of Nutrition and Dietetics*118:112-122.

Bouis HE and Saltzman A (2017) Improving nutrition through biofortification: A review of evidence from HarvestPlus, 2003 through 2016. *Global food secu*rity, 12, pp.49-58.

Dhliwayo T, Palacios-Rojas N, Crossa J and Pixley KV (2014) Effects of S1 recurrent selection for provitamin A carotenoid content for three open-pollinated maize cultivars. *Crop Science* 54*:* 2449-2460.

Dube N, Mashurabad PC, Hossain F, Pullakhandam R, Thingnganingd L and Bharatraja DK (2018) β-Carotene bioaccessibility from biofortified maize (*Zea mays*) is related to its density and is negatively influenced by lutein and zeaxanthin. *Food and Function* 9: 379-388.

Duo H (2019) Genetic and biochemical evaluation and molecular marker analysis of locally adapted *crtRB1*-based inbreds for provitamin-A enrichment in maize. M.Sc thesis submitted to ICAR-Indian Agricultural Research Institute, New Delhi.

Foreign Agricultural Service/USDA. (2019) Office of global analysis. https://ipad.fas.usda.gov/. Accessed on June, 2019.

Gebremeskel S, Garcia-Oliveira AL, Menkir A, Adetimirin V and Gedil M (2017) Effectiveness of predictive markers for marker assisted selection of pro-vitamin A carotenoids in medium-late maturing maize (*Zea mays* L.) inbred lines. *Journal of Cereal Scien*ce **79:** 27-34.

Giuliano G (2014) Plant carotenoids: Genomics meets multi-gene engineering. *Current Opinion in Plant Biology* 19:111-117.

Global Nutrition report (2017) Retrived from website https://www.globalnutritionreport.org.

Goswami R, Zunjare RU, Khan S, Baveja A, Muthusamy V and Hossain F. (2019) Marker‐assisted introgression of rare allele of *β-carotene hydroxylase* (*crtRB1*) gene into elite quality protein maize inbred for combining high lysine, tryptophan and provitamin A in maize. *Plant Breeding* 138:1-10.

Gupta HS, Hossain F, Muthusamy V and Zunjare RU (2019) Marker-Assisted Breeding for Enrichment of Provitamin A in Maize. In *Quality Breeding in Field Crops* (pp. 139-157). Springer, Cham.

Harjes CE, Rocheford TR, Bai L, Brutnell TP, Kandianis CB, Sowinski SG, Stapleton AE, Vallabhaneni R, Williams M, Wurtzel ET and Yan J (2008) Natural genetic variation in *lycopene epsilon cyclase* tapped for maize biofortification. *Science* 319:330-333.

Hossain F, Sarika K, Muthusamy V, Zunjare RU and Gupta HS (2019) Quality Protein Maize for Nutritional Security. In *Quality Breeding in Field Crops* (pp. 217-237). Springer, Cham.

Liu L, Jeffers D, Zhang Y, Ding M, Chen W, Kang MS and Fan X (2015) Introgression of the *crtRB1* gene into quality protein maize inbred lines using molecular markers. *Molecular Breeding* 35: 154.

Manjeru P, Biljon AV and Labuschagne M (2017) The development and release of maize fortified with provitamin A carotenoids in developing countries. *Critical Reviews in Food Science and Nutrition* https://doi.org/10.1080/10408398.2017.1402751.

Mayer JE, Pfeiffer WH and Beyer P (2008). Biofortified crops to alleviate micronutrient malnutrition. *Current Opinion in Plant Biology* 11:166-170.

Menkir A, Maziya-Dixon B, Mengesha W, Rocheford T and Alamu EO (2017) Accruing genetic gain in provitamin A enrichment from harnessing diverse maize germplasm. *Euphytica* 213:1-12.

Muthusamy V, Hossain F, Nepolean T, Saha S, Agrawal PK, Guleria SK and Gupta HS. (2015a) Genetic variability and inter-relationship of kernel carotenoids among indigenous and exotic maize (*Zea mays* L.) inbreds. *Cereal Research Communications* 43:567-578.

Muthusamy V, Hossain F, Thirunavukkarasu N, Choudhary M, Saha S, Bhat JS, Prasanna BM and Gupta HS. (2014) Development of β-carotene rich maize hybrids through marker-assisted introgression of *β-carotene hydroxylase* allele. *PLoS ONE* 9(12):e113583.

Muthusamy V, Hossain F, Thirunavukkarasu N, Saha S and Gupta HS. (2015b) Allelic variations for *lycopene-ε-cyclase* and *β-carotene hydroxylase* genes in maize inbreds and their utilization in β-carotene enrichment programme. *Cogent Food & Agriculture* 1:1033141.

Pixley K, Rojas NP, Babu R, Mutale R, Surles R and Simpungwe E. (2013) Biofortification of maize with provitaminA carotenoids. In Carotenoids and human health, Humana Press, Totowa, NJ, 271-292.

Sagare DB, Shetti P, Surender M and Reddy SS (2019) Marker-assisted backcross breeding for enhancing β-carotene of QPM inbreds. *Molecular Breeding* 39:174-183.

Simpungwe E, Dhliwayo T, Palenberg M, Taleon V, Birol E, Oparinde A and Diressie MT. (2017) Orange maize in Zambia: crop development and delivery experience. African *Journal of Food, Agriculture, Nutrition and Development* **17**: 11973-11999.

Sommer A and Davidson FR. (2002) Assessment and control of vitamin A deficiency: the Annecy Accords. *Journal of Nutrition*132:S2845-S2850.

Sommer A and West KP. (1996) Vitamin A deficiency: Health survival and vision. New York, Oxford University Press.

Tanumihardjo SA. (2011) Vitamin A: biomarkers of nutrition for development. The American *Journal of Clinical Nutrition* 94:658S-665S.

Vignesh M, Hossain F, Nepolean T, Saha S, Agrawal PK, Guleria SK, Prasanna BM and Gupta HS. (2012) Genetic variability for kernel β-carotene and utilization of *crtRB1* 3'TE gene for biofortification in maize (*Zea mays* L.). *Indian Journal of Genetics and Plant Breeding* 72:189-194.

WHO (2009) Global prevalence of vitamin A deficiency in population in risk 1995-2005. http://www.who.int/nutrition/ publications/ micronutrients/ vitamin-A deficiency/ 9789241598019 /en.

Yadava DK, Hossain F and Mohapatra T (2018) Nutritional security through crop biofortification in India: Status & future prospects. The *Indian Journal of Medical Research* 148: 621.

Yan J, Kandianis CB, Harjes CE, Bai L, Kim EH, Yang X, Skinner DJ, Fu Z, Mitchell S, Li Q and Fernandez MGS (2010) Rare genetic variation at *Zea mays crtRB1* increases β-carotene in maize grain. *Nature Genetics* 42:322.

Zunjare RU, Chhabra R, Hossain F, Muthusamy V and Gupta HS. (2018a) Molecular characterization of 5'UTR of *lycopene epsilon cyclase (lcyE)* gene among exotic and indigenous inbreds for its utilization in maize biofortification. 3Biotech 8:75. https://doi.org/10.1007/s13205-018-1100-y.

Zunjare RU, Hossain F, Muthusamy V, Baveja A, Chauhan HS, Bhat JS, Thirunavukkarasu N, Saha S and Gupta HS (2018b) Development of biofortified maize hybrids through marker-assisted stacking of *β-carotene hydroxylase*, *lycopene-ε-cyclase* and *opaque2* genes. *Frontiers in Plant Science* 9:178 doi: 10.3389/fpls.2018.00178.

Zunjare RU, Hossain F, Muthusamy V, Baveja A, Chauhan HS, Thirunavukkarasu N, Saha S and Gupta HS (2017). Influence of rare alleles of *β-carotene hydroxylase (crtRB1)* and *lycopene epsilon cyclase (lcyE)* genes on accumulation of provitamin A carotenoids in maize kernels. *Plant Breeding* doi: 10.1111/pbr.12548.

MAIZE PROCESSING AND VALUE ADDITION - KEY FOR MAIZE GROWTH

Shobha, D
AICRP on Maize, Zonal Agricultural Research Station, Mandya

Cereals along with pulse combinations constitute an important part of human diet in many parts of the world due to their easy availability, low cost, long shelf life and nutritional balance. During recent past, India has made significant progress in improving the food security of its masses. The green revolution of 60's helped the country in achieving the food security by improving the availability and access components. However, Surplus quantity of food produced is not uniformly distributed and the quality component is not addressed properly which has a direct impact on nutrition. In spite of surplus production of food grains still malnutrition persists. Malnutrition can suitably be overcome by combining cereals with good quality pulses and other value addition techniques which will go long way in solving the problem of malnutrition along with better price for the crop.

Even though our country is producing variety of cereals, pulses and millets, utilization of produced grains to their fullest potential is not happening and third largest produced maize is not an exception. The consumption of corn is very less in our country which may be due to the lack of awareness regarding the nutritional benefits, method of processing, cooking and to some extent availability of other foods in refined and processed forms. However, owing to superiority of maize over rice and wheat due to its high fiber, phosphorus, beta-carotene and free from gluten lends itself suitable for people who are allergic to gluten. Gluten allergy, also known as celiac disease, is an autoimmune disease that occurs because of ingestion of a protein, called gluten, which is present in the cereals – wheat, rye and barley. In these patients, the gluten protein is not digested completely and that leads to damage in mucosa of small intestine, where food is absorbed. With the damage of the small intestine, the food is not absorbed and thus, these patients fail to grow in height and weight, develop chronic diarrhea, anemia (low hemoglobin) and weakness of bones. In India 6 to 8 million people are suffering from gluten intolerance. In order to counteract the gluten allergy problem, one needs to take foods which are devoid of gluten. In place of wheat other foods like rice, maize, sorghum pear millet, dhal, vegetables, milk and non vegetarian food are best suitable to fulfill nutritional requirement of body.

Maize also known as corn, has many industrial and food applications apart from its use as a feed ingredient. It is rich in starch and bland to taste making it an exceptional choice as an ingredient in several traditional foods. Like other cereals, maize contains large proportion of carbohydrates (60-65%) and thus provides bulk of energy in the diets based on it. Apart from carbohydrates it is also a good source of protein (10-12 %), fat (3.5-5.5 %) and crude fiber (2.0-2.5 %). By virtue of its composition it is quite comparable to rice and wheat in its nutritional value (Table 1).

There are many maize based products manufactured and marketed at commercial scale. Several of these products are now industrialized on a small or large scale by many food industries. In USA over 1000 different items can be found on the shelves of a typical supermarket and they are derived wholly or partially from maize. These products include tortillas, maize flours (masa), chips and several types of snack, breakfast cereal, thickeners, pastes, syrups, sweeteners, grits, maize oil, soft drinks, beer, whisky etc.

Table 1. Nutritional quality of maize compared to rice and wheat (per 100g)

Grain	**Carbohydrate (g)**	**Protein (g)**	**Fat (g)**	**Crude fiber (g)**	**Minerals (g)**	**Ca (mg)**	**P (mg)**	**Iron (mg)**
Maize	66.2	11.4	4.6	2.7	1.5	10	348	2.3
Rice (milled)	77.6	6.80	0.5	0.2	0.7	10	100	0.7
Wheat	71.2	11.8	1.5	1.2	1.5	41	306	5.3

Processing and consumption of maize

Maize is being processed in various ways in different parts of the world before consumption. However, several traditional food processing and preparation methods can be used at household level to enhance the bioavailability of micronutrients in maize based diets. These methods include alkali cooking, thermal processing, mechanical processing, soaking, germination/malting and fermentation. However, soaking and nixtamalization are the major pre treatments followed around the world.

Nixtamalized maize or lime treated or alkali treated grain

This process was developed by Native American Indians. The nixtamalization consists of mixing one third part of whole maize with two third part of lime (calcium hydroxide) solution between 1 to 2 per cent of concentration. In general the cooking time may vary from 15 to 45 minutes and the temperature of cooking is held above 68^0 C. The dry masa flour is more stable against rancidity and the shelf life was found to be up to six months in comparison with the whole kernel ground maize flour.

↓ After cleaning
Soak 500g grains in 1% lime water for 5 minutes
(10g of lime in 1 liter water)
↓
Give heat treatment at simmering temperature for 30 minutes
↓
Remove the vessel and leave it for overnight
Wash 3 – 4 times to remove lime
↓
Dry in sunlight
(Moisture level should be 9-10 %)
↓
Store in air tight container

Fig 1. Lime treatment of maize grains

Nixtamalization or lime treatment has several advantages like it facilitates the peri carp removal, controls microbial activity, enhances water uptake, increases gelatinization of starch with improvement in nutritional value through an increased availability of niacin. The research conducted at AICRP (Maize), Mandya, indicated that the lime treated maize flour can be kept up to three months in LDPE covers without affecting the flavor and roti making quality. The process of lime treatment and its advantages have been disseminated through training to maize growers, SHG's and mill owners. The lime treated corn is also used in India for the preparation of various products such as *roti, dumpling,* snack foods such as *sev, muruku* and *laddu* by suitably combing with pulses.

Nutritional enrichment or fortification of maize with other cereal / pulse combinations

Since the need for nutritive food at low cost is in demand and majority of the population in different geographical areas depend on cereals for their daily needs. Wherever QPM is not available in such places, the better alternative is to combine the maize with good quality pulses such as soybean, green gram, bengal gram, black gram, groundnut along with wheat, rice, ragi in desired combinations. The concept of multi grains or multigrain flour is more ideal not only for nutritional and cost benefits but also to improve the texture and shelf life of the products. A number of products can be prepared from this multi grain flour which can also be included in mid day meal programmes in Schools and Anganawadis to serve the balanced food at lower cost. Since maize flour is gluten free, it can be recommended for people who are intolerant to gluten *i.e.,* it can replace chapathi with roti of maize flour. The unique property of maize dough is its ability to hold more water than other cereal dough (22.89 – 25.64%) and it is the reason why maize roti has been found to be quite soft and supple. The use of maize flour, either singly or in combination with the flours of other cereal or legume flours for making many types of sweet and savoury snack foods has great possibilities in the Indian context. Different types of deep fried products are possible and have been tried. For example noodles, pasta, vermicelli prepared by the low pressure extrusion using maize flours or a mixture of maize flour with that of gram (chick pea) flour can give excellent, crisp deep fried *sev*. In this respect, maize flour can be a good extender of gram flour (bengal gram) for such preparations. A large variety of sweet dishes like *laddu, burfi, Mysorepak*, *etc*. can also be prepared from maize flour. Number of conventional as well as fancied items such as papad, crispies, sev, *muruku* , *energy bars* , Ready to cook (RTE) mixes such as *idli mix*, *vada mix*, *nutri mix, bisibelebath mix*, *maize suji bath mix* (sweet and savory) are already popular in Karnataka.

Specialty Corns

Maize is also being grown for diverse uses and specialty purposes and maize for specialty and value added purposes are collectively called "**specialty corn**". Compared to field corns, specialty corns possess additional characteristic features like tender-ear, biochemical components relating to sweetness, protein, starch and popping traits. Their global spread, increasing demand and premium price make them an attractive option for the farmers in many countries including India. The major specialty corns which occupied significant portion in food shelves include baby corn, sweet corn and pop corn.

Table 2: Nutritional quality of baby corn, sweet corn and popcorn (per 100 g)

Nutrients	Baby corn	Sweet corn	Pop corn
Energy (K.Cal)	42.20	86.0	382
Moisture (%)	89.10	75.0	16.0
Carbohydrates (%)	8.20	18.70	78.0
Protein (%)	1.90	3.27	12.0

Fat (%)	0.20	1.35	4.0
Crude fiber (%)	1.56	2.0	15.0
Iron (mg)	0.10	0.52	2.70
Calcium (mg)	28.0	2.0	3.10

Baby Corn

Baby corn refers to the young cobs of maize harvested within 1-4 days of silk emergence. Baby corn is highly nutritive and its nutritional quality is at par or even superior to some of the seasonal vegetables. It is one of the richest source of phosphorus. Baby corn cobs are free from residual effects of pesticides as the young cobs are wrapped up within the husk and well protected from diseases, insects, fungicides and insecticides.

Processing of baby corn: Important processing methods which can be used to improve the shelf life of baby corn are canning, dehydration and freezing.

Canning: The most common method used for processing of baby corns and is normally practiced by dipping corn in brain solution (NaCl solution) and can be stored for months and transported to far off places.

Dehydration: One of the oldest methods to increase the shelf life with less expenditure. Baby corn can be cut into round or 2 cm long pieces and dried in an oven or can be solar dried. Dried baby corn can be packed in polythene pack, vacuum pack, tetra pack and can be stored for longer period. Dehydrated cobs can be rehydrated by soaking in water and used in any sweet or savoury preparations.

Freezing: Baby corn cobs can be frozen at -18 to -24^{0}C and stored for longer period like other frozen vegetables. They can be used effectively for the preparation of food products like salads, curry and soup preparations.

Baby corn may be consumed raw or used as an ingredient in various preparations. Different value added products such as *manchurian, jam, pickle, pakoda, curry, salad, soups, halwa,* canned corns etc. are few examples under wide range of value added products. At AICRP (Maize),Mandya, centre we have standardized the process for preparation of baby corn candy using 40, 50 and 60^0 brix sugar solution followed by dehydrating the same till the moisture level reaches between 6-8 per cent. The prepared candies will have a shelf life of six months in MPP pouches. We have also standardized the technology for the preparation of *baby corn candy, baby corn lollypop, brined baby corn, baby corn murabba, dehydrated baby corn, minimally processed baby corn* etc are standardized and the same has been disseminated to stake holders.

Sweet Corn

Sweet corn (*Zea mays saccharata*) is known to possess a specific endosperm mutation like su and sh. In India, sweet corn green ears are being consumed by direct toasting on fire or boiled in water. Sweet corn kernels often have a wrinkled appearance resulting from a sugary gene which retards the normal conversion of sugar to starch during endosperm development. Kernel colors vary sometimes being mixed both white and yellow. The endosperm is composed of sweetish starch and characterized by translucent horny appearance during immature stages and after maturity the kernel becomes wrinkled. Sweet corn cob is normally harvested around

80-85 days after sowing (milky stage). It contains on an average 15- 25 % total soluble solids (TSS). Many sweet and savoury dishes such as *halva*, *kadabu*, *crunch*, *salad, jam*, *pakoda* and many more products can be prepared using sweet corn.

Pop Corn

Pop corn (*Zea mays var. everata*) has small grains with hard outer layer. It has higher *per cent* of hard starch than flint corn. It is a popular snack throughout the world. Pop corn is an extreme form of flint corn, wherein there is a variation in the proportion of hard starch and soft endosperm. The moisture in the soft starch at the central portion of the endosperm on heating is converted to steam and when this steam tries to escape it is confined by the outer layers of hard endosperm. When the steam pressure increases the hard pericarp of the seed bursts into flakes leading to the phenomenon called "popping" Popping is one such technique of grain processing where in the germ and bran portions are retained and it is the most simplest and economical method of processing which imparts a pleasant aroma and flavor that can be enjoyed by people at all times.

Popped Grain: Optimally the minimum moisture to preserve crispiness in popped grain should be less than 2 per cent. Moisture also affects the texture of pop corn and hence must be consumed at moisture lower than 2 per cent (ideally 1.8-1.7%).Popped grains are good in terms of energy, carbohydrate, fat, fiber, protein and iron. Popping is simple and economical processing technique which is traditional and may be adopted easily with improvement in nutritional quality. It is a high temperature short time (HTST) treatment (180-232°C) which sterilizes product, gelatinizes its starch and develops a pleasant aroma to form a ready-to-eat food (RTE) at a very low processing cost. Popping process not only retains the actual nutritional profile of grains but also markedly enhances its protein digestibility, bio availability of iron and dietary fiber content due to the development of resistant starch. The ground pop corn in the form of flour or grits can be used in the preparation of many traditional dishes. Popcorns are usually consumed as a snack food with or without salt (regular), sweetened (caramel/chocolate corn) or butter like topping. Popcorn consumption has greatly increased in recent years because of the advent of microwavable popcorn as well as the proliferation of flavored ready to eat products with good nutrition.

Value addition to popped grains: At AICRP (Maize), Mandy centre ground popcorn with various sized grits are utilized in the preparation of many traditional as well as fancied dishes including health mixes (sweet and savoury), spicy pop corn, sweetened pop corn, chocolate pop corn, iron rich pop corn pre mix, energy dense pre mix, fiber rich laddu, pop corn lolly pop, pop corn bar, burfi and others.

Quality Protein Maize (QPM)

Quality Protein Maize (QPM) contains opaque-2 gene (o2) which makes it different from normal grains. Although maize contains higher proportion of protein (10-12 %) its quality is poor as compared to that of protein in rice due to presence of high concentration of alcohol soluble protein fraction 'prolamine' also known as 'Zein' in the endosperm. Zein is very low in some essential amino acids, mainly lysine and tryptophan which contribute more than 50 % of the total protein. On the other hand, very high amount of leucine and imbalanced proportion of isoleucine contribute to poor quality of protein in normal maize. To overcome such deficiencies, scientists developed Quality Protein Maize (QPM) where in, the quality of protein is not only superior to the common maize, but also significantly higher than that of other cereal grains. Lysine and tryptophan in QPM genotypes was increased compared to that of normal grain. The balanced proportion of all these essential amino acids in QPM has increased the protein quality and their biological value (Table 3 and 4). The "zein" fraction is reduced between 10 to 13 per cent in QPM as against 39 per cent in normal maize. The nutritional and biological superiority of QPM has been demonstrated in the diets of infants, small children and adults, particularly women.

Table 3: Chemical composition of Common maize (CM) and Quality Protein Maize (QPM)

Nutrients (% DM)	**CM**	**QPM**
Carbohydrate (%)	72.80	73.14
Crude protein (%)	8.91	9.42
Fat (%)	4.66	4.87
Crude fiber (%)	3.51	3.03
Ash (%)	0.97	1.02
Calcium (%)	0.22	0.18
Phosphorus (%)	0.28	0.32
Energy (kcal/kg)	335	338

Table 4: Amino acid content in common maize (CM) and quality protein Maize (QPM)

Amino acid	**CM (CP-8.90%)**	**QPM (CP-9.42%)**
	AA (% in CP)	**AA (% in CP)**
Methionine	1.99	1.81
Cystine	2.13	2.77
Met+ Cystine	4.12	4.58
Lysine	2.89	3.95
Threonine	3.45	3.65
Tryptophan	0.73	0.90
Arginine	4.53	6.38
Isoleucine	3.28	3.06
Leucine	12.22	8.80
Valine	4.59	5.10
Histidine	2.85	3.74
Phenylalanine	4.94	4.09

Quality protein maize (QPM) for food and nutritional security:

QPM can be utilized for diversified purposes in food and nutritional security. The nutritious products developed from Quality Protein Maize (QPM) can replace fancied and highly priced industrial foods with a diversified ways under food and nutrition security as infant foods, health foods, convenience foods, specialty foods and emergency rations.

Good number of products from QPM was developed at AICRP (Maize), Mandya centre and studied their nutritional quality and storage stability and found that QPM products are quite similar to normal maize products in organoleptic and storage quality. However, they are superior in nutritional quality when compared to normal maize products. Some of the popular products such as *maize noodles, maize vermicelli, maize papad, maize ready-to-cook idli mix, maize ready-to-cook vada mix, maize nutri mix, maize nutri laddu and maize upma mix* were developed and commercialized under the brand name "**MAIZY**"

Contribution of AICRP (Maize), Mandya centre towards value addition and popularization of maize:

Value addition to maize is important to make maize a nutritionally enriched and acceptable grain. The Quality Protein Maize (QPM) which has better amino acid balance can be utilized in diversified ways. Technologies developed at AICRP (Maize) like lime treatment of grains, milling, extrusion enrichment with other ingredients and enhancing their palatability through standardization process have been adopted by stakeholders to make maize a viable ingredient for value addition. Maize processing unit established at the centre has plant and machinery such as dry mill, papad maker, noodle making machine, pasta unit, dryer and pop corn maker and these were used in the production of flour, semolina, papad, pasta, vermicelli, crispies and RTC products such as nutri mix, idli mix and vada mix from maize. Around 250 SHG women and small entrepreneurs were trained in the processing, value addition, packing and marketing of the products. Commercially, the maize value added products were sold by an entrepreneur (M/S **Aaaradhya of Aaradhya Agro Food and Beverages, Mysore)** under the brand name **Maizy**. The nutritious products of QPM can replace fancied and highly priced industrial foods. These products can also be prepared in villages with minimum machinery and could be great source of rural entrepreneurship. Thus QPM based rural industries have a wider scope for employment generation and rural prosperity.

Opportunities in India to popularize maize as major food grain: There are number of ways to popularize maize as a food grain and the potential opportunities are provided below.

- ✓ Bio-fortified maize (lysine, tryptophan, provitamin Aand Vitamin E) may find important place among health conscious urban population as consumers are ready to pay 20-70% premium price for the biofortified foods.
- ✓ Attractive labeling and suitable branding**:** highlighting the health benefits on products made from biofortified maize or gluten free products would help the consumers to choose more nutritious foods over conventionally available ones.
- ✓ Various food products from QPM such as "Pusa-shakthi", Kheer-mix, "Proteino-H", Maizy suji, Maizy flour (Atta), "Maizy noodles and Pasta", offer attractive options to the urban Policy decisions to achieve and sustain high value for maize.
- ✓ Contract Farming and buy-back policy or farm loan would ensure continuous supply of grains to the industry.
- ✓ Technologies such as lime treatment enhance the shelf-life of grains and value-added products provide excellent opportunities to develop small scale industry and in turn empower village women.
- ✓ Inclusion of biofortified maize in the rural transformation project of "NITI AAYOG" and other government sponsored programme like "National food security mission (NFSM)" and "Rashtriya Krishi Vikas Yojana (RKVY)" as well as nutrition

intervention programme such as "Integrated child development scheme (ICDS)" and 'mid-day meal' would help in further popularization.

- ✓ Government should change its policies so that farmer can grow the diversified food crops in place of mono cropping, because after independence due to the government policies (minimum support price (MSP), Public distribution system (PDS) and procurement mechanism) little bit biased towards the rice and wheat in place of balanced approach. If farmers grow diverse food crops at their farm definitely over dependency on wheat get reduced and other cereals are focused as "gluten free alternative"

PROSPECTS OF BIOLOGICAL CONTROL OF FALL ARMYWORM *SPODOPTERA FRUGIPERDA* IN INDIA

A.N. Shylesha
Principal Scientist Entomology
ICAR-National Bureau of Agricultural Insect Resources, Bengaluru

After invasion of fall armyworm (FAW), *Spodoptera frugiperda*, in 2018, a survey was conducted in major maize growing area of Karnataka state. The initial survey was conducted in the districts of Chikkaballapur, Hassan, Mandya, Chikkamagaluru, Shimoga, Davanagere, Chitradurga and Raichur. During survey, the incidence of fall armyworm was recorded on 20 to 60 days old crop coinciding with different phenological stages. The initial incidence of FAW ranged from 9 to 65% among the district surveyed. In 2018, at initial stage of fall armyworm infestation in maize, the higher incidence of pest was recorded in Hassan (62.5%) followed by Davanagere (55.5%), Shimoga (48.5%) and Chikkaballapur (47.5%). During survey, the larvae feeding on tassels were recorded, but no infestation on cob stages was observed. The early stage of maize crop was more vulnerable to pest infestation.

Currently, the incidence of fall armyworm was observed on the maize from, Telangana, Maharashtra, Tamil Nadu, Bharuch, Gujrat, West Bengal, North Eastern States and from Bihar and Uttar Pradesh and the infestation has spread to almost all the states of India.

Natural enemies

During survey, naturally infected or parasitized larvae of FAW were collected. From the eggs of fall armyworm an egg parasitoids, *Trichogramma* sp. and *Telenomus* sp. was collected. However, natural parasitism of larval parasitoids, *Campoletis chlorideae* Uchida, *Chelonus* sp., *Cotesia* sp., *Phenerotoma* sp.and *Eriborus* sp was recorded on the larval stage of fall armyworm. The natural infection of entomopathogenic fungi, *Metarhizium rileyi* (Farl.) Kepler, S.A. Rehner & Humber (= *Nomuraea rileyi* [Farl.] Samson) was also recorded on different larval stage of fall armyworm.

Several parasitoids were obtained from Fall armyworm from Karnataka which included, Trichogramma sp. Trichogramma pretiosum, Telenomus remus, egg larval parasitoid Chelonus sp. and larval parasitoids like *Glyptapanteles creatonoti* (Viereck) (Hymenoptrea: Braconidae), *Apanteles creatonoti* Vier, *Compoletes* chloridiae and several predators like earwig *Forficula sp,* predatory bugs like *Andrallus spinidens, Eocanthecona furcellata* were recorded to be highly beneficial in the management of Fall armyworm. In addition one dipteran parasitoid *Pseudgourax sp* was also recorded on the egg mass of Fall armyworm. The maggots were found feeding on the eggs thereby showing a potential for management of FAW. Efforts were made to mass rear some of them and released for the management of FAW.

Mass rearing of *Chelonus* spp. Egg – Larval Parasitoid of Fall Army Worm *Spodoptera frugiperda* (J. E. Smith): *Chelonus* spp., egg – larval parasitoids were recorded frequently from field samples collected from different districts of Karanataka, India since March, 2018 - incidence of Fall Army Worm *Spodoptera frugiperda* (J. E. Smith) was reported and was alerted across the country. The parasitoid specimens were processed for identification – both morphological and molecular taxonomy and Genus was confirmed as *Chelonus* spp.: a – Small & Arrehenotokous & b. Big & Arrehenotokous. Species level identification of these parasitoids are in progress. Adults of *Chelonus sp.* (a) were exposed to the eggs of natural hosts - *S. frugiperda*, *Spodopter litura* (Fabricius) and laboratory host - *Corcyra cephalonica* (Stainton) in different rearing units: Homeopathic vials, Borosil test tubes and pearl pet jars of 0.5 kg, 1 kg and 5 kg in the BOD set at 25 ± 2°C and Relative humidity 65± 5%. Exposure period was 48 hrs. Hatched neonates were reared on artificial diet media. Adult longevity varied from 2 – 7days. Developmental period was found to be 20 to 25 days on natural host and 25 to 50 days in *Corcyra*. Percent parasitism was 10 to 19.4 and 45 to 57.5 % of adults could successfully emerge from cocoons reared on natural host whereas 85 to 98% adult emergence was recorded for Corcyra eggs. Successful rearing on Corcyra eggs enabled mass rearing and release of *Chelonus* sp. for management of Fall armyworm in maize crops during monsoon and post – monsoon seasons in different villages of Karnataka, India.

Mass rearing of *E. Furcellata and Andrallus spinidens* major predators of FAW

The adults and egg masses of *E. furcellata* and *Andrallus*. *spinidens* were collected from organic maize fields of GKVK, Bangalore. Bugs were reared on different hosts, *S. frugiperda S. litura* , *Samia cynthia ricini* (Drury) and *Corcyra cephalonica* (Stainton) in the laboratory conditions (25 ± 2 °C, 60% ± 10% RH) NBAII, Bangalore. The second generation of *E. furcellata* was used for experiments. The bugs were kept in plastic jars covered inside by blotting paper and provided with disease free larvae as regular food along with leaves. Jars were covered with muslin cloth for aeration. Eggs deposited by female bugs on the leaves and on blotting paper will be kept separately in the plastic boxes with sieve cap for hatching. Provide wet cotton immediately after the emergence. Ten numbers of each nymphal instars and adults will be provided with second and third instars of *S. frugiperda* larvae as prey to determine the functional response. The number of prey larvae consumed will be recorded daily and the dead larvae will be replaced with live ones. Currently the rearing of these two predatory bugs are standardized.

More than 10 parasitoids and 5 predators are active on FAW under field conditions which are keeping the spread of the insect under check in addition to the incidence of *Nomuraea rileyi* and NPV which are a major factor for management of the invasive fall armyworm. A continued effort and supply of egg parasitoids like *Trichogramma*, *Telenomus* and *Chelonus* sp. Can bring down the population of fall armyworm in maize ecosystem.

Production Practices for Doubling Farmers Income Through speciality corn cultivation-An efficient diversification to achieve the goal

Dilip Singh
AICRP on Maize, Maharana Pratap University of Agriculture and Technology, Udaipur
dilipagron@gmail.com

Maize is the third most important cereal crop that is considered as integral component of food security at global level. In India it is an important crop not only in terms of acreage but also in context to their versatility for adoption under wide range of agro-climatic conditions.

Maize is a versatile crop with uses ranging from industrial products to food preparations, as well as direct human consumption at vegetative stage. Of the different forms used for human consumption, major per cent is consumed as staple food in various forms *viz.*, bread, biscuits, cookies or transformed into corn flakes, soups, fresh-roasted sweets, boiled cobs and vegetables *etc*. Maize grain is main ration for poultry birds.

Now a days cultivation of speciality corn *viz.,* "QPM, sweet corn, pop corn and baby corn" is the need of hour. In tribal areas the corn varieties used for human consumption have low protein content with unbalanced composition of essential amino acids. In these varieties, the content of essential amino acids *viz.,* lysine and tryptophan are low while leucine and isoleucine content are high (Jat *et al.,* 2009). The low protein and unbalanced composition of amino acids content in corn cause protein deficiency diseases like kwashiorkor and malnutrition in the poor class people who have maize as principle dietary source (Singh, 2010). The high yielding single cross hybrid of quality protein maize developed by breeders and popularly known as 'QPM' assumes a great significance in overcoming problem of malnutrition in tribal population of country where maize is raised as staple food crop. There is enormous scope to increase cultivation of QPM further due to increasing global demand, value added potential and better prices in market as compared to the traditional varieties of maize. With the development of poultry and livestock industry, its consumption as animal feed has also increased tremendously.

Likewise use of sweet corn cobs at immature stage as roasted and boiled ears is a popular practice as the kernels are sweet, creamy, tender, crispyand tastes almost shell-less. Sweet corn is a hybridized variety of maize specifically bred to increase the sugar content. Due to its sweet taste and tenderness, cultivation and demand of sweet corn is increasing in India and in the international market. Increasing attention is now being paid to explore potential of sweet corn in India. After harvesting green cobs, plant of sweet corn is used as green fresh fodder or dry fodder.

In addition to these, pop corn have smooth, rounded pearl like corn with pointed hard, flinty endosperm that surrounds a small amount of soft moist starch at the centre. Heating the kernel turns this moisture into steam which expands, splits the seed coat and causes the starch to explode in good quality pop. The pop corn is nutritionally rich food (Kumar *et al.* 2012). Due to its immense nutritional value and high remunerative commercial value, cultivation of pop corn is another choice of farmers now a days. Similarly "Baby corn" is the immature cob used for table purpose as salad or cooked as vegetable. After harvesting cobs, plants of baby corn are used as green/dry fodder.

Considering the importance of nutritionally rich and highly remunerative speciality corn and its huge demand in the country, the present farmers tendency is to grow speciality corn at commercial level to augment the income of the farming community dwelling in the outskirts of big cities and metropolis (Suthar *et al.,* 2014). Since there is limited scope to increase the area under speciality corn cultivation because of competition from other cereal and cash crops, the only alternative is through enhancement of productivity by various agronomic management factors.

The Challenge

The overwhelming majority of small and marginal farmers live in rural areas in the country. They are typical cultivators of small plots, from which they get neither sufficient crop production nor income to ensure house hold food security. These small & marginal farmers could double the crop output and income generated from these small plot if they had access to key ingredient of income *i.e.* the speciality corn cultivation. With an assured market, farmers can grow suitable speciality corn and earn higher income in maize growing areas of country.

Along with raising small-farm productivity, access to speciality corn cultivation is also the key to improve livelihood and revitalizing rural economy. It creates jobs for people both with and without land, since more people are needed to harvest, process and market the crop and to supply farm inputs, thus generating employment and higher income for off-farm workers as well. Thus the spread of speciality corn cultivation technologies can form backbone and lift the income of poor farmers sustainably.

Management strategies

Suitable varieties: Being a commercial crop, selection of speciality corn and its variety is most important in the speciality corn cultivation. On the basis of market and requirements, preference should be given to early to medium maturing single cross hybrids. For baby corn it should be with multiple cob bearing ability and regular row arrangement, with high sucrose in sweet corn, better popping quality pop (button mushroom shape) in pop corn and bold and bright colour grain with high lysine and tryptophan content varieties in case of QPM.

Sowing time: The speciality corns *viz.,* QPM, pop corn, sweet corn and baby corn varieties may be sown round the year. However, under highly low temperature days during winter season sowing of speciality corn may be avoided. Maintaining time isolation with little early/delayed planting compared to routine planting of maize maintains better quality of speciality corn.

Sowing method: During commercial cultivation of speciality corns *viz.,* baby corn and sweet corn, the sowing should be done in blocks with 7-10 days time interval. It will enhance the period of baby corn and sweet corn availability in market and and also the efficient utilization of the farm resources.

Plant population and seed rate: An optimum plant population of 83,333 plants ha^{-1} for sweet corn and pop corn is to be maintained for higher and quality sweet and pop corn yield by keeping 60 x 20 cm distances between rows and plants after thinning. A little higher geometry *i.e.*1,00,000 plants ha^{-1} is maintained for baby corn by planting maize at 50 x 20 cm spacing. The plant population of 66,666 or 83,333 plant $ha^{-1}$is to be maintained for quality protein maize by planting it at 60 x 25/20 cm spacing. Little higher seed rate (20-25 kg ha^{-1}) is required for baby corn production due to more plant population requirement. Contrary, the seed rate is less in sweet corn (6-8 kg ha^{-1}) and pop corn (10-12 kg ha^{-1}) because of shrivelled and smaller seed, respectively. A normal seed rate of 18-20 kg ha^{-1} is recommended for QPM cultivation.

Seed treatment: For management of major maize diseases namely PFSR, TLB, MLB, BLSB, downy mildew *etc.* and major insect like shoot borer, termite, FAW *etc.* an integrated insect pest and diseases management strategy involving seed treatment with fungicide and bio-control agent *Trichoderma*, selection of tolerant variety and spraying of need based fungicide/insecticides will be useful.

Nutrient management: Nutrient application should be based on soil test basis. In soils having medium nitrogen, phosphorus, potassium and zinc status, an application of 90-120 kg nitrogen, 40-60 kg phosphorus, 30-40 kg potash and 20-25 kg $ZnSO_4$ ha^{-1}is sufficient for realizing potential yields of sweet corn, pop corn and baby corn. The quality protein maize being slow utilizer of nutrients needs higher doses of fertilizers. In QPM an application of 120-200 kg nitrogen, 60-80 kg phosphorus, 60-80 kg potash and 20-25 kg $ZnSO_4$ ha^{-1} with 8-10 tons ha^{-1} FYM should be applied for realizing potential yield. Full dose of phosphorus, potash and zinc should be applied as basal dose, however, nitrogen should be applied in three split application *viz.,* 1/3 at sowing, 1/3 at knee high stage and rest 1/3 at 50 per cent tasseling stage. Being slow utilizer of nutrient, nitrogen in QPM should be applied in four equal split application at sowing, knee high, 50 per cent tasseling and grain filling stages. The technologies of SSNM, STCR and green seeker based fertilizer application proved economically beneficial.

Weed management: likewise normal maize, in speciality corn broad leaf weeds and most of the grasses can be controlled by pre-emergence spray of Atrazine @ 0.5 to 1.0 kg *a.i.* ha^{-1} in 500-600 litre of water followed by one hoeing at 20-35 days after sowing. Under intercropping, pre-emergence spray of Pendimethalin @ 0.75 kg *a.i.* ha^{-1} followed by one hoeing at 20-35 days after sowing controlled broad spectrum weed flora in the field. The post plant spray of Tembotrione 90-120 ml ha^{-1}or Topramezone 25 g ha^{-1} at 20-25 days after sowing also controlled broad spectrum weed flora in maize alone. The other practices such as crop residue mulching, zero/reduced tillage is also useful for control of weed flora.

Water management: The 60-80 per cent of total area of maize is under rainfed condition wherein low rainfall and uneven distribution of rainfall leads to dry period during crop season that often decreases yield potential and consequently income of the farmers. As the rainfall is most important source of water, the capture and efficient use of rainfall is most critical component for sustainable crop production. Therefore efficient conservation of rain water in soil or by harvesting the runoff and recycling it for supplemental irrigation is important for speciality corn cultivation. The supplemental irrigation to be applied should be life saving. Irrigation should be given as and when required by the crop depending upon the rains and moisture holding capacity of the soil. Young seedlings, knee high stage and tasseling & silking are the most sensitive stages for water stress for crops and irrigation should be ensured at these stages.

Intercropping: The speciality corn is more remunerative, if it is cultivated with intercrops. An area specific 20 crops, namely potato, green pea, cabbage, cauliflower, sugar beet, green onion, garlic, fenugreek, coriander, knol-khol, broccoli, lettuce, turnip, radish, carrot, celery, gladiolus, *etc.* have been successfully cultivated as intercrop with speciality maize (Kumar *et al.,* 2012). There is no adverse affect of intercrops on speciality corn and vice-versa, rather, some of the intercrops help in improving soil fertility and protects the corn crop from cold injury. The short duration varieties of intercrops may be preferred for intercropping with speciality corns. Recommended dose of fertilizers of intercrops should be applied in addition to the recommended doses of fertilizers of speciality corns

Harvesting: The harvesting of baby corn and sweet corn needs some precautions. The baby corn should be harvested when the silks are 1-2 cm long, *i.e.* within 1-2 days after silk emergence. Further de-tasseling before silking is essential practice in baby corn. The removed tassel should not be thrown in the field but fed to the cattle as it is nutritive fodder. In single cross hybrid plant, 3-4 pickings may be obtained. Harvested de-husked baby corn may be stored for 3-4 days at 10^0C without much effect on its quality. For long term storage and distant transport, baby corn is canned in brine solution (3%), sugar (2%) and citric acid (0.3%) solution and stored under refrigerated conditions. Baby corn may also be stored in vinegar. The sweet corn should be harvested when the grains are in dough stage *i.e.* 15-20 days after silking. The pop corn and QPM should be harvested at full maturity stage.

Cropping system: The speciality corn and other crop species that are cultivated may play an important role in sustaining and maintaining soil health. Crop rotations that include legume crops and reduced tillage are an important factor in maintaining soil health and must be adapted to any cropping system with speciality corn cultivation. Crop rotations also affect the biological diversity of an agro-ecosystem. The biological diversity is important for maintaining a high-functioning, disease-resistant and stable ecological system. Crop rotations that maximize soil carbon inputs and maintain a high proportion of active carbon are important factors in establishing a sustainable cropping system. Cropping systems and management practices that ensure greater amounts of crop residue returned to the soil are expected to cause a net build-up of the soil carbon stock. Thus suitable systems or practices with speciality corn should be adapted for sustaining soil health and productivity (Ghosh *et al.,* 2018).

Conclusion

On the basis of adaptability and suitability, speciality corn based cropping system produce adequate returns from land within the constraints of unpredictable climate conditions and limited inputs. Income obtained per unit area of speciality corn based cropping system will be much more than from normal maize based cropping system. It is economically viable, environmentally sustainable and ensures rural prosperity in the maize growing area and communities of country. Thus maize growing farmers can increase their income by four times with adoption of speciality corn based cropping system. However, the traditional practice of growing maize without good agricultural practices leads to exploitation of the soil resources. In addition to the economic benefits, the speciality corn based cropping systems ensure employment, food and nutritional security coupled with sustainability and environmental services.

References

Ghosh PK, Hazra KK and Nath CP (2018) Soil carbon management through crop diversification and sustainable intensification. *XXI Biennial National Symposium of Indian Society of Agronomy,* 24-26 October, 2018.

Jat ML, Dass S, Yadav, Sekhar VK and Singh DK (2009) Quality protein maize for food and security in India. *Directorate of Maize Research, IARI, New Delhi* (http://www.maizeindia.org).

Kumar R, Das AK, Kaul J, Karjagi CG, Kumar B, Choudhary DP, Sapna, Kumar RS, Dass S, Yadav AK, Singh D and Kumar S (2012) Speciality corn cultivation in India. *Directorate of Maize Research, Technical Bulletin, IARI, New Delhi.*

Singh D (2010). Impact of scheduling of nitrogen on productivity of single cross maize (*Zea mays* L.) hybrids. *Indian Journal of Agricultural Science* 80: 649-651.

Suthar M, Singh D, Nepalia V and Singh AK (2014). Performance of sweet corn (*Zea mays* L.) varieties under varying fertility levels. *Indian Journal of Agronomy* 59:168-170.

BREEDING FOR LOW PHYTIC ACID MAIZE – STATUS AND PROSPECTS

Chikkappa G. Karjagi[1], Alla Singh[2], Ramesh Kumar[2], Shyam Bir Singh[3], Yathish KR[4], Abhijit Kumar Das[2], Sunil Neelam[4], Shivraj Singh Gangoliya[15], Arun Kumar[1], Ujjwal Kapoor[1], Hemant Kumar Yadav[1], Shraddha Srivastava[1] and Sujay Rakshit[2]

[1]Unit Office, ICAR-Indian Institute of Maize Research, New Delhi
[2]ICAR-Indian Institute of Maize Research, Ludhiana
[3]Regional Maize Research and Seed Production Centre, ICAR-Indian Institute of Maize Research, Begusarai
[4]Winter Nursery Centre , ICAR-Indian Institute of Maize Research, Hyderabad
[5]Maharana Pratap Government Post Graduate College, Gadarwara
chikkappagk@gmail.com

Seed bio-mineralization is an important biochemical process by which the mature seeds reserve some of the essential macro- and micro-nutrients required during germination. One of the most widely studied seed bio-mineralization process is the storage of seed phosphorous (P) and other important cations namely calcium (Ca), potassium (K), Magnesium (Mg), Manganese (Mn), Iron (Fe)and Zinc (Zn) in phytate or phytic acid (PA) salts. The seed bio-mineralization is provide essential micro- and macro-nutrients to germinating seeds through their mobilization; most the above mentioned mineral elements act as an important co-factors in several metabolic processes; either directly or indirectly determine the function or efficiency of several enzymes which catalyze several biochemical processes. However, sometimes the level of such reserves in some of the crops like maize, soybean, barley, wheat and many other crops are so high that the level is not only well above the requirement by the germinating seeds but also affects the bio-availability of such nutrients in animals which depend on these crops for their dietary nutritional requirement. In this context, PA has been termed rightly as anti-nutritional factor and it is an important challenge to reduce its level without compromising the overall germination and vigour of the seedlings in different crop species.

The distribution of the phytate and other essential mineral elements in different parts of the seeds especially in cereals were studies (O'Dell et al. 1972). The results suggested that >80% of the total phosphorous is stored in the form of PA. The distribution of PA among different parts of the seeds has shown that approximately 80-90% of the PA is stored in germ (maize) or pericarp (rice) or aleurone layer (wheat); differential storage organ depending upon the type of grain or crop. Raboy et al (1990) for the first time in maize surveyed the level of PA in different maize mutants. The study on different mutations has gave an opportunity to explore for breeding for low phytic acid in maize as the study has indicated that the mutants which affect the embryo reduced the PA substantially without reducing the total P; the corresponding increase in the inorganic phosphorous (Pi) was observed. In maize, several mutant alleles in three different gene(s) namely *lpa1*, *lpa2*and *lpa3* which affect three important critical steps in PA biosynthesis namely PA transportation, insositol phosphate kinases (IPK) or myo-insositol kinases (MIK) have been identified (Raboy et al. 2000 and Shi et al. 2005).

The first effort to transfer of LPA mutant *lpa1-1* into different genetic background mainly the elite lines of hybrids was attempted as early as 1998. Several near isogenic lines (NILs) by transferring *lpa1-1* have been developed and isohybrids using such NILSs have also been developed. The performances of such resultant isohybrid were evaluated for various agronomic and different yield-component traits across multiple locations. The results had shown that the hybrids have showed normal growth and development from germination to harvesting. The hybrids have shown good stalk strength/ standability and also comparable traits for flowering and other yield contributing traits. (Ertl et al. 1998, Raboy, 2002). In recent years, the availability of molecular markers linked to gene(s) determining low phytic acid traits has facilitated breeders to mobilize such mutant alleles across different genetic background through marker assisted selection (MAS). In case of maize, few elite inbred lines are converted by transferring LPA mutants like lpa1-1 (Naidoo et al. 2012), lpa2-2 (Tamilkumar et al. 2014, Sureshkumar et al. 2014a, 2014b). However, the low phytic hybrids have as yet not released in India commercial cultivation.

Presently in India, several hybrids are under pipeline with low-phytic acid mutant alleles which are at various developmental stages. The hybrids are being developed through marker assisted backcross breeding (MABB).

References

Ertl D Young KA Raboy V. (1998) Plant genetic approaches to phosphorus management in agricultural production. *J. Environ. Qual*. 27: 299-304.

Naidoo R Watson GMF, Derera J, Tongoona P, Laing M. (2012) Marker-assisted selection for low phytic acid (lpa1-1) with single nucleotide polymorphism marker and amplified fragment length polymorphisms for background selection in a maize backcross breeding programme. *Molecular Breeding*, 30: 1207–1217.

O'Dell BL, de Boland AR, Koirtyohann SR (1972) Distribution of phytate and nutritionally important elements among the morphological components of cereal grains. *J. Agric. Food Chern*. 33: 1179-1182.

Raboy V, Gerbasi PF, Young KA Stoneberg SD, Pickett SG, Bauman AT, Murthy PPN, Sheridan WFand Ertl DS. (2000) Origin of seed phenotype of maize low phytic acid 1-1 and low phytic acid 2-1. *Plant Physiol.* 124, 355–368.

Raboy V. (2002). Progress in breeding low phytate crops. *J. Nutr.*, 132: 503S-505S.

Shi J, Wang H, Hazebroek J, Ertl DS, Harp T. (2005) The maize low-phytic acid 3 encodes a myo-inositol kinase that plays a role in phytic acid biosynthesis in developing seeds. *Plant Journal* 42: 708– 719.

Sureshkumar S, Tamilkumar P, Thangavelu AU, SenthilN, Nagarajan P, Vellaikumar S, Ganesan KN, Balagopal R, Ravindran M. (2014b) Marker-assisted introgression of lpa-2 locus responsible forlow-phytic acid trait into an elite tropical maize inbred. *Plant Breed*., 133: 566-578.

Tamilkumar P, Senthil N, Sureshkumar S, Thangavelu AU, Nagarajan P, Vellaikumar S, Ganesan KN, Natarajan N, Balagopal R, Nepolean T, Raveendran M. (2014) Introgression of low phytic acid locus (lpa2-2) into an elite Maize (Zea mays L.) inbred through marker assisted backcross breeding. *Aust J Crop Sci* 8:1224–1231

PHYTIC ACID IN MAIZE – A BOON OR A BANE

John Joel A[1], Lydia Pramitha.J[2], Ravikesavan.R[3], Firoz Hossain[4] and Sujay Rakshit[5]

[1,2,3]Tamil Nadu Agricultural University, Coimbatore

[4]ICAR-Indian Agricultural Research Institute, New Delhi

[5]ICAR-Indian Institute of Maize Research, Ludhiana

Maize originated as a temperate crop evolved by domestication of a Mexican annual teosinte, *Zea mays* ssp. *parviglumis*, native to the Balsas River valley in south-eastern Mexico, with up to 12 per cent of its genetic material obtained from *Zea mays* ssp. *mexicana* through introgression. This theory was further confirmed by the 2002 study of Matsuoka *et al.,* (2002). Present day maize is highly evolved and can be grown over a wide range of agro-climatic zones and this quality makes it a versatile crop. Maize is suitable to be grown from 58°N to 40°S, from below sea level to altitudes higher than 3000 m, and in areas with 250 mm to more than 5000 mm of rainfall per year (Tripathi *et.al.,* 2011) and with a growing cycle ranging from 3 to 13 months. However, the major maize production areas are located in temperate regions of the globe. The United States, China, Brazil and Mexico account for 70 per cent of global production. India has 5 per cent of maize acreage and contributes 2 per cent of world production (AICRP Annual Report 2007).

The use of maize varies in different countries. Maize is used mainly as a feed for animals directly or sold to industries dealing with feed and fodder and as raw material for extractive/ fermentation industries in the US, EU, Canada and other developed countries, (Dado *et.al*., 1999) and whereas main use of maize is for food in Latin America and Africa. In Asia maize is being utilized for human nutrition as well as animal nutrition. In other developing countries utilization pattern of maize is variable. The fact is that maize is being exploited and consumed in many countries and it is an important ingredient in the diets of people. According to an estimate approximately 21 per cent of the total grain produced is consumed as food globally.

In Indian scenario, maize is the third most important food grain following wheat and rice. About 28 per cent of maize produced is utilized for food purpose, about 11 per cent for livestock feed, 48 per cent for poultry feed, 12 per cent in wet milling industry (for example starch and oil production) and 1 per cent as seed goes in India (De Bosque *et al*,.2007). The highest growth rate for the maize has been registered in the last one decade among all food grains including wheat and rice because of newly emerging food habits, consumer awareness about health as well as enhanced industrial requirements.

More than half of the total maize production of India is produced in four states of Madhya Pradesh, Andhra Pradesh, Karnataka and Rajasthan. In spite of wide range of health benefits offered by maize as a source of hugh fiber, antioxidants and other vitamins and minerals, major portion of maize is still not being used for human consumption and goes for poultary and animal feed (Lott et al., 2000). While utilizing as animal or poultry feed, the major constrain in maize grain is the presence of phytic acid, which hinder the bioavailability of nutrients when consumed by monogastric animals (Nelson *et.al*., 1968).

Phytic acid in maize

Phytic acid (myo-inositol hexaphosphate, $InsP_6$, or phytate) is present in most of the cereal grains, which provides myo-inositol and phosphorus which is essential for normal seed germination and seedling establishment. Among the cereals, maize seed alone produces approximately 4.8 million metric tons of phytic acid annually around the globe (Selle *et al.,*2006) Phytic acid is the most abundant P-containing compound in mature seeds, typically representing from 65% to 80% of the mature seed's total P (Bohlke *et al.,*2005). In the mature maize (*Zea mays*) seed, most (80%) of the phytic acid is found in the germ with the remainder in the aleurone layer (O'Dell *et al.,*1972). Phytic acid in maize grains is poorly digested by monogastric animals and negatively affects animal nutrition and the environment. As a result, feed has to be supplemented with P_i to meet the phosphorus requirement for optimal animal growth. The undigested phytic acid excreted from monogastric animals is considered as a leading source of phosphorus pollution from agriculture (Raboy *et al.,*2006). In addition, the presence of phytic acid in the animal feed and human food reduces the bioavailability of essential mineral cations, such as Fe^{3+}, Zn^{2+} and Ca^{2+} due to its chelating ability in animals and humans. Hence, intake of cereals which are rich in phytic acid are also forming a reason for the nutritional deficiency (Cosgrove *et al.,*1980).

To overcome this, in animal feed industry, treatment of animal feeds with food grade phytase, an enzyme that can cleave the phosphate groups of hexa- and penta phosphate forms of phytic acid, is extensively used. In human food, fermentation, malting, soaking, and germination are some food preparation methods that can be used to reduce the phytate contents of foods (Cosgrove *et al.,*1980). But, the acceptability, practicality, and sustainability of these methods in various areas may be limited and to overcome these, breeding programmes to evolve low phytic acid (*lpa*) inbreds and *lpa* hybrids have been attempted (Raboy *et al.,*2000).

Conventional plant breeding combining molecular techniques can be used to reduce the phytic acid content of seeds. By selecting low phytic acid (*lpa*) genotypes, the phytate content of cereals may be reduced considerably, resulting in enhanced zinc absorption (Hambidge *et al.,*2004). This would provide a sustainable way to improve zinc nutrition of human populations. We therefore evaluated the effects of several novel low *lpa* genotypes of maize (Zea mays L.) and this would help in evolving *lpa* lines and thereafter *lpa* hybrids with low phytic acid (Pramitha *et al.,*2019). Most of the low phytate lines are known to have negative pleiotropic effects such as reduced seed set ratio, seedling growth and thus this study was carried out to identify lines having better combining ability for producing low phytate elite hybrids (Bregitzer *et al.*,2006).

Breeding approaches

Utilization of germplasm and development of reference set for *lpa*

In order to restrain the difficulties in handling a large number of germplasm and to work with a small collection without loss of alleles for the trait of interest, developing a reference set from the large germplasm collection is practiced. A reference set consists of a set of accessions selected from a base population in such a way that it follows a normal distribution for the concerned trait (Upadhyay *et al.*,2008). This enhances the utilization of germplasm in breeding programs and enables the breeders to handle a manageable population. Here the available 338 germplasm accessions at the Department of Millets, Tamil Nadu agricultural University were screened to form a reference set of 58 genotypes without loss of allelic variations. In both the population, the variability for phytic acid in the grains ranged from 2.77 to 16.70 mg/ g. The reference set was formed with random genotypes selected from the base population to follow a normal distribution. The skewness, Kurtosis and K-S test for normality (Dn) were found to be 0.17, 0.61, 0.70 respectively for phytic acid content in grains (Figure 1) with non-significant difference between the means of the base and the reference set was obtained (Pramitha *et al.,*2019). This further ensured the entire representation of the base in the formulated reference set for phytic acid with the maximum variability from the base population.

The morphological and biochemical characterization of this reference set revealed a significant positive correlation existing between the yield and yield contributing traits namely, kernel yield, number of kernels per row, ear diameter and ear length with the phytic acid content. This exhibits the negative effects of reducing the phytic acid content of the grains and similar reductions in yield levels of the *lpa* mutants have also been observed in other studies of maize, barley and wheat (Campion *et al.,*2013, Bregitzer *et al.,*2008 and Pramitha *et al.,*2019).

The variability of the formulated reference set revealed, six major principal components with flowering traits (days to 50% tasseling, days to 50 per cent silking and anthesis silking interval), ear height and phytic acid contributing favorably to all the major six principal components. This persuades the effectiveness of selection for these traits from the formulated reference set and this would enable the breeders to handle minimum population for further grouping the genotypes to analyze their heterotic potential combined with low phytic acid (Pramitha *et al.,*2019).

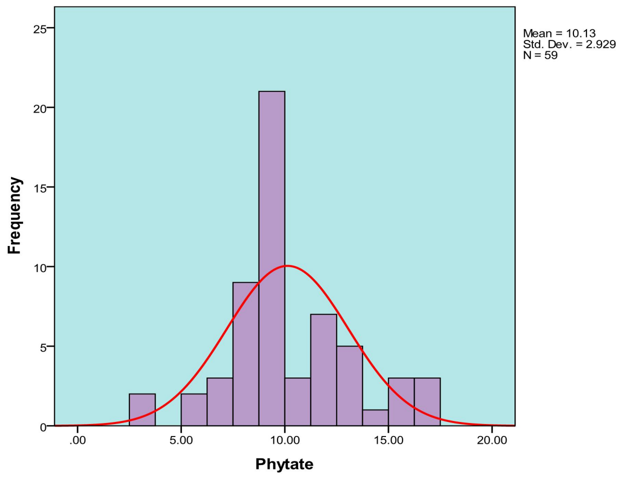


Figure 1: Distribution of phytic acid in the newly formulated reference set

Genes responsible for phytic acid and characterized in maize

The phytic acid in plants is synthesized via two pathways *i.e.* lipid dependent and lipid independent pathway (Sparvoli and Cominelli,2015). The first is predominant in all the plant tissues and the latter is predominant in seeds. The genes involved in the phytic acid biosynthesis has been well characterized in Arabidopsis, rice, wheat, soybean, maize and common bean through the screening of *lpa* mutants and is reported to be the major growth regulating factors during the embryonic stages. There are eight main classes of genes encoding phytic acid viz., MIPS, IMP, MIK, 2-PGK, IPK-2, ITK, IPK1 and MRP. These genes belong to the small gene families except for MIK which is encoded by a single locus.

Accordingly, in maize, three mutants have been isolated and characterized with reduced phytic acid content. They are *lpa* 1 *lpa* 2 and *lpa* 3. Among the three mutants, *lpa* 1 had 66% of reduction in phytic acid and is caused by a gene that is responsible for the transmembrane transporter protein ZmMRP4. This gene is known to play a key role in the transfer of phytic acid to storage vacuoles in seeds. The *lpa* 2 is due to the mutation in the ZmIPK4 gene. The *lpa* 2-1 is a resultant of the sequence rearrangement of ZmIPK and *lpa*-2-2 is by a transition of cytosine to thymine at the position 158. This eventually causes a stop codon in the open reading frame of N-terminal, ZmIPK (Sureshkumar *et al.,*2014). The *lpa* 3 is caused by a gene that codes for myoinositol kinase. These identified mutant lines serves as an essential genetic resource for developing low phytic acid lines in maize (Sparvoli and Cominelli,2015).

Molecular breeding approaches:

The identified low phytic acid lines by Raboy *et al.,*2000 were subtropical and had consisted of negative pleiotropic effects of reduced phytic acid content. This makes it more difficult for the breeders to incorporate it as parents in hybrid development. Hence, an lpa-2-2 line, EC-659418 was used as a donor and the lpa-2-2 was introgressed to an elite line UMI-285 by the use of an allele specific marker Umc 2230 through marker assisted back cross breeding program. Four lines with reduced seed phytic acid and favourable agronomic parameters like 100 seed weight and grain yield were screened from 350 BC_2F_3 progenies (Figure 2). These lines could be promisingly used for developing better parental lines to produce low phytate hybrids without compromising the yield related traits (Suresh Kumar *et al.,*2014 and Tamilkumar *et al.,*2014).

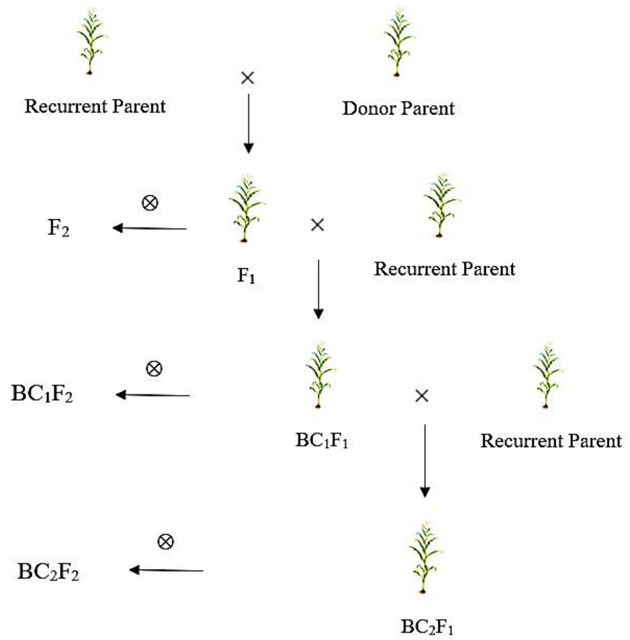


Figure 2: Marker assisted backcross of *lpa2-2*

Stability of phytic acid

Several hybridization and introgression of elite lines have been focused for producing low phytic elite lines and one of the major prejudices in developing these lines was to analyze its stable expression. The free myoinositol that produces phytic acid in plants is also an essential component in many pathways including auxin, cell wall polysaacharides, osmolytes (pinnitol) and lipid biosynthesis. Hence, the phytic acid is expected to vary across environmental conditions. In wheat, oats and sorghum, phytic acid was observed to be varying in seasons and locations (Nahapetian and Bassiri,1976 and Brankovic *et al.,*2016).

Further the characterization of the reference set also revealed seasonal and yearly variations in the phytic acid content (Jacob *et al.,*2016). Hence the potential lines from the reference set were subjected to a stability analysis across three locations. There were four potential and stable pre-breeding lines viz., UMI-467, UMI-447, *LPA*-2-395 & *LPA*-2-285 obtained from this analysis and they had a stable low phytic acid content across locations. Four lines viz., UMI-113, UMI-300-1, UMI-158 and UMI-1099) were moderately stable and they were observed to vary in an rainfed environment (Figure 3) (Pramitha *et al.,*2019). This suggests the adjustments in the plant myoinositol for the producing osmolytes to cope up with the external stimuli (Brankovic *et al.,*2016). Across the locations, the phytic acid was negatively and significantly correlated to the free inorganic phosphorous (Chandhana *et al.,*2018) and the potential stable donors for *lpa* had the highest level of free inorganic phosphorous in them (Figure 5) (Pramitha *et al.,*2019b). These stable lines even though were uniform for their phytate content had a poor adaptability in comparison to the elite checks. The seeds of the stable donors were shriveled with poor cob and germination characteristics (Figure 4) (Pramitha *et al.,*2019b). This entrusts the role of phytic acid in seed set and pollination (Donahue *et al.,*2010).

Phytic acid is well known to accumulate after anthesis in plants in order to sequestrate the essential micronutrients and proteins for the seed development and germination [32,33,56,60]. Therefore, alterations in their existing content had consecutively lead to the poor seed and cob developments in low phytate lines (Bregitzer *et al*.,2006). These results suggest the adoption of proper selection criteria and breeding methodologies in developing low phytic acid lines in maize. Selection techniques by pursuing a threshold phytic acid by selecting medium phytate lines with lesser negative effects and introgression of these low phytic acid to elite backgrounds could be an alternate strategy to utilize better parental sources for producing elite low phytate hybrids (Pramitha *et al.,*2019c). This also opens a research thrust in identifying the molecular and genetic reason beneath the stability of these stable lines in future for its complete utilization in breeding programs.

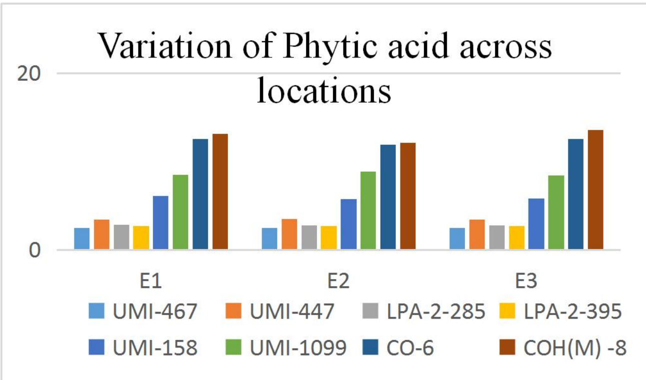


Figure 3: Variation of phytic acid

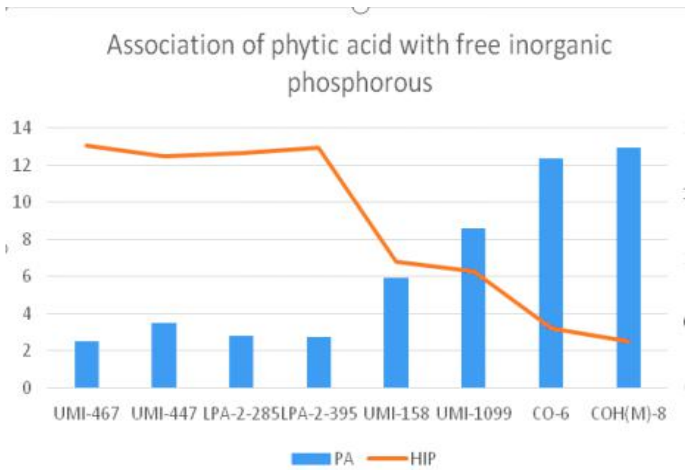


Fig 4: Negative relationship of phytic acid with inorganic phosphorous

Formulating a hybridization programme and heterotic potential of phytic acid

The introgression of the lpa trait by means of hybridization to elite lines paves a new scope of developing low phytic acid lines in maize. Thus the identified stable donors of low phytic acid were crossed to elite maize inbreds from the Department of Millets. Two fashions of crosses with eight lpa lines as testers with elite inbreds as lines in one way and the vice versa were formulated to produce low phytate hybrids. The phytic acid content of the resultant hybrids ranged from 4.50 to 11.21 mg/g in the first fashion and 4.62 to 13.63 mg/g in the second fashion. In both these designs the hybrids were lower than the commercial check. The hybrids although were similar in mean yield levels with the check failed to surpass the standard check's yield. This presents the influence of the reduction in the phytic acid content of all the crosses obtained. The lowest stable phytic acid content with positive *sca* for yield and a yield closer with to the check was observed in UMI-1200 x UMI-467 (Pramitha *et al.,*2019b). The poor germinability and seedling vigour reported in *lpa* crosses by Naidoo *et al*.,2012 were not observed in these experimental designs (elite x *lpa* & *lpa* x elite) due to the presence of an elite parent as male/female in the hybridization programs to combat the negative pleiotropic effects of the *lpa* donors (Pramitha *et al.,*2019b & Vengilat *et al.,*2019).

A diallel approach among the potential stable donors for *lpa* were also experimented simultaneously and the resultant hybrids had a very poor seed set with adverse germination pattern, seedling vigour, plant height and yield. The previous studies of *lpa* x *lpa* crosses [87] had abnormal germination and development, whereas in this approach although few seeds germinated, they did not express any hybrid vigour and were drastically poor. Hence, from all these strategies, it could be suggested that phytic acid is essential for plant's vital development and breeding programs should be framed in such a way to minimize the effects of its reduction. The plant requires a minimum threshold of phytic acid and drastic reductions are expected to yield embryo abnormalities. Therefore, utilizing elite parental sources with lpa introgressed lines could serve as a genetic asset to further develop high yielding hybrids in maize. These identified parental lines are an essential source for further research experiments and they were grouped into two heterotic groups A and B (Vengilat *et al.,*2019). This heterotic grouping could further be elaborated by addition of other potential donors for yield and phytic acid to favor rapid production of elite *lpa* hybrids in maize.

References

AICRP. All India Coordination Research Project (AICRP) on Maize (2007) 50th Annual Report by Directorate of Maize Research, Indian Council of Agriculture Research (ICAR),Pusa, New Delhi pp-6.

Bohlke RA, Thaler RC, Stein HH (2005) Calcium, phosphorus, and amino acid digestibility in low-phytate corn, normal corn, and soybean meal by growing pigs. *J. Anim. Sci.* 83:2396–2403.

Branković G, Dragičević V, Dodig D, Knežević D, KandićV, Šurlan-Momirović G, Sečanski M, (2016) Phytic acid, inorganic phosphorus, antioxidants in bread and durum wheat and their associations with agronomic traits. *Agricultural and Food Science 24*(3):183-194.

Bregitzer P, Raboy V, Obert D, Windes J, Whitmore J (2008) Registration of Clear water low-phytate hulless spring barley. *J. Plant Regist. 2:*1–4.

Breitzer P, Raboy V (2006) Effects of four independent low-phytate mutations on barley agronomic performance. *Crop Sci* 46:1318-1322.

Campion B, Glah R, Tava A, Perrone D, Doria E, Sparvoli F, Cecotti R, Dani V, Nielsen (2013) Genetic reduction of anti-nutrients in common bean seed increases nutrients and in vitro iron bioavailability without depressing agronomic traits. *Field crop Res* 141-27-37.

Chandhana AS, John Joel A, Ravikesvan R, Uma D (2018) Genetic variability and correlation studies of yield and phytic acid in F_2 populations in maize. *Electronic journal of plant breeding* 9(4):1469-1475.

Cosgrove DJ (1980) Inositol Phosphates: Their Chemistry, Biochemistry and Physiology. *Elsevier Scientific Publishing Company*, Amsterdam, 26–43.

Dado RG (1999) Nutritional benefits of specialty maize grain hybrids in dairy diets, *Journal of Animal Science* 77 (Suppl. 2) /*Journal of Dairy Science* 82 (Suppl.2):197-207.

De Bosque C, Castellanos EJ, (2007) Bressani R in INCAP Report Annual, INCAP, Gautemala, 75:198

Donahue JL, Alford SR, Torabinejad J, Kerwin RE, Nourbakhsh A, Ray WK, Hernick M, Huang X, Lyons BM, Hein PP, Gillaspy GE (2010) The Arabidopsis thaliana myo-inositol 1-phosphate synthase1 gene is required for myo-inositol synthesis and suppression of cell death, *The Plant Cell 22(*3):888-903.

Hambidge KM, Huffer JW, Raboy V, Grunwald GK,Westcott JL, Sian L, Miller LV, Dorsch, J A, Krebs NF (2004) Zinc absorption from low phytate alleles of maize with and their wild-type iso hybrids. *Am. J. Clin. Nutr*. (79):1053–1059.

Jacob George (2016) Identification of elite parents and hybrid development in maize for low phytic acid, PG Dissertation, Tamil Nadu Agricultural University, Coimbatore, India.

Lott JNA, Ockenden I, Raboy V, Batten GD (2000) Phytic acid and phosphorus in crop seeds and fruits: a global estimate. *Seed Sci. Res.* 10:11-33.

Matsuoka Y, Vigouroux Y, Goodman MM, et al. (2002) A single domestication for maize shown by multilocus microsatellite genotyping. *Proceedings of the National Academy of Sciences*. 99(9)6080–4.

Nahapetian A, Bassiri A (1976) Variations in concentrations and interrelationships of phytate, phosphorous, magnesium, calcium, zinc, and iron in wheat varieties during two years. *J.Agric.Food.chem*. 24:947-950.

Naidoo R, Tongoona P, Derera J, Laing MD, Watson GMF (2012) Combining ability of low phytic acid (lpa1-1) and quality protein maize (QPM) lines for seed germination and vigour under stress and non-stress conditions, *Euphytica* 185(3):529-541.

Nelson TS, Shieh TR, Wodzinski RJ, Ware JH (1968) The availability of phytate phosphorus in soybean meal before and after treatment with a mold phytase. *Poult. Sci.*47:1842-1848.

O'Dell BL, de Boland AR, Koirtyohann (1972) Distribution of phytate and nutritionally important elements among the morphological components of cereal grains. *J Agric Food Chem* 20:718–721.

Paramasivam T, Natesan S, Subbaraj S, Arumugam UT, Pothiraj N, Sampathrajan V, Kalipatty NG, Nagappan N, Ramachandran B, Thirunavugarasu N, Muthurajan R (2014) Introgression of low phytic acid locus *(lpa2-2)* into an elite Maize (*Zea mays* L.) inbred through marker assisted backcross breeding, AJCS 8(8):1224-1231.

Pramitha LJ, John JA, Srinivas S, Sreeja R, Hossain F, Ravikesavan, R (2019) Enumerating the phytic acid content in maize germplasm and formulation of reference set to enhance the breeding for low phytic acid.*Physiol Mol Biol Plants.*0970-0430.

Pramitha LJ (2019b) Stability analysis and heterotic studies in maize (*Zea mays* L.) inbreds for identification of elite hybrids with low phytic acid and high quality protein. Ph.D thesis, Tamil Nadu Agricultural University, Coimbatore.

Pramitha LJ, John JA, Jacob G, Sreeja R, Ravikesavan R (2019c) Studies on genetic parameters and combining ability in maize for the production of hybrids with low phytic acid. *Electronic Journal of Plant Breeding*, 10 2: 419-429.

Raboy V (2006) Seed phosphorus and the development of low-phytate crops. In Inositol Phosphates: Linking Agriculture and Environment. *CAB International:Oxfordshire, U.K.*111-132.

Raboy V, Gerbasi P, Young KA, Stoneberg S, Pickett SG, Bauman AT, Murthy PPN, Sheridan WF, Ertl DS (2000) Origin and seed phenotype of maize low phytic acid 1-1 and low phytic acid 2-1. *Plant Physiol.*124:355–368.

Selle PH, Ravindran V, Bryden WL, Scott T (2006) Influence of dietary phytate and exogenous phytase on amino acid digestibility in poultry.: *a review. J. Poult. Sci*. 43:89–103.

Sparvoli F Eleonora Cominelli (2015) Seed biofortification and phytic acid a conflict of interest for the plant? *Plants* 4:728-755.

Sureshkumar S, TamilKumar P, Senthi N, Nagarajan P, Thangavelu AU, Raveendran M, Vellaikumar S, Ganesan KN, Balagopal R, Vijayalakshmi G, Shobana V (2014) Marker Assisted selection of low phytic acid trait in Maize. *Heriditas* 15: 120-27.

Tripathi KK, Warrier R, Govila OP, Ahuja V (2011) Biology of *Zea mays*.L (Maize). Department of Biotechnology, Ministry of Science and Technology and Ministry of Environment and Forests, Government of India.

Varsha PV (2019) Heterotic grouping of the maize inbreds for the production of low phytic acid hybrids. PG Dissertation, Tamil Nadu Agricultural University, Coimbatore.

Upadhyay HD, Dwivedi SL, Baum M, Varshney RK, Udupa SM,Gowda CL, Hoisington D, Singh S (2008) Genetic structure,diversity and allelic richness in composite collection andreference set in chick pea (Cicer arietinum L.) *BMC Plant Biol* 8:106.

CONSERVATION AGRICULTURE IN MAIZE SYSTEMS: A WAY FORWARD FOR SUSTAINABILITY

S.L. Jat, C.M. Parihar[1], A.K. Singh, Sreelatha D.[2], D.M. Mahala, S.D. Bamboriya, Radheshyam[1] and P.V. Kadam[1]
ICAR-Indian Institute of Maize Research, Ludhiana
[1]ICAR-Indian Agricultural Research Institute, New Delhi
[2] Professor Jayashankar Telangana State Agricultural University, Hyderabad

The present cropping systems facing challenges of sustainability due to arising problems of the soil sickness and decreasing input use efficiency. This is further aggravated by the fast-changing climate having aberrant weather conditions, which pose a serious threat to the sustainability of agriculture in the world and India in particular. The conservation agriculture (CA) based crop management practices are found effective for mitigating effects of climate change due to lesser greenhouse gas emissions compared to the conventional system of agriculture. These practices also found effective for adaptation of the climate change effect due to changes in soil health and microclimate modification. The CA is the set of practices based on three cardinal principles of minimal soil disturbance, retention of residue as soil cover and profitable sustainable crop rotation. The CA has adopted over 185 m ha areas in the world. To potentially make the Indo-Gangetic Plains (IGP) productive in a sustainable manner, conservation agriculture (CA) has to be effectively adopted and out scaled into the existing agricultural system (Jat et al., 2016). However, the adoption of the CA in India is still very less (1.5 m ha) as it was targeted in a limited number of the cropping systems. The maize is one of the fastest-growing crops in India due to increased maize demand for remunerative prices and availability of best technologies for easier and higher production. The crop area of maize now reached close to 10 m ha and the upcoming areas as well as traditional areas if targeted with CA will be sustainable and more profitable. Hence, we enumerated the potential of CA in maize system with special reference to India in this paper for improving profitability and soil health for sustainable crop production.

CA and crop productivity, resource efficiency and profitability in maize systems

Various workers in the country researched CA in maize systems intensively. The enhancement in maize yield was significantly higher with the application of the residue by 12.6% over no residue application in conservation agriculture (IIMR, 2019) which underlies importance of the residue retention in the CA in maize systems In a 6-year study of CA evaluated the performance of CA-based management practices [permanent bed (PB) and zero tillage (ZT)] and conventional till (CT) for four intensified irrigated maize systems [maize-wheat-mungbean (MWMb), maize-chickpea-*Sesbania* green manure (MCS), maize-mustard-mungbean (MMuMb) and maize-maize-*Sesbania* (MMS)]. Significant ($P < 0.05$) tillage and cropping system interactions were observed for system productivity (Parihar et al., 2016). In the initial two years, higher system productivity (maize equivalent yield) was recorded in PB (8.2–8.5 Mg ha^{-1}), while from third year onwards ZT registered maximum productivity (11.3–12.9 Mg ha^{-1}). Net profit from the maize-based systems under ZT was up to 31% higher with 72$ ha^{-1} lower production cost compared to CT. Compared to the rice-wheat system, increased system productivity (up to 33%) and profitability (up to 50 %) was observed in CA-based maize-wheat system (IIMR 2019).

The maize, wheat and mustard yields were statistically similar in first year of study irrespective of residue retention or removal, whereas during subsequent years, yields of maize, wheat and mustard were significantly ($P < 0.05$) higher by 10.1–16.7%, 9.3–23.6% and 13.6–21.9% under residue retained plots (full CA) than residue removed plots (partial CA), respectively (Jat et al., 2019a). Crop residue retention in zero tilled PB increased cost of cultivation by 125 and 147 USD/ha in MMuMb and MWMb systems, respectively (Jat et al., 2019c).

Experiments on nutrient management in maize-based cropping system under different tillage practices have also shown encouraging results. In maize-wheat-mungbean cropping system, zero tillage resulted in significantly higher crops yield and site-specific nutrient management (SSNM) gave higher yield over farmer's fertilization practices (FFP) and RDF at Banswara. In rice-maize cropping system, at Dholi the tillage practice of permanent beds (PB) resulted in significantly higher cob yield and site-specific nutrient management (SSNM) gave higher yield over farmer's fertilization practices (FFP) and RDF in grain yield and RDF found statistically at par Planting of maize-mustard/chickpea system under rainfed condition planting of maize with zero tillage resulted in 7.0-11.6% higher yields in various zones (IIMR, 2017).

ZT and PB practices reduced the irrigation water requirement by 40–65 ha-mm and 60–98 ha-mm, respectively compared to CT system and resulted in enhanced system water productivity by 19.4% equally under both ZT and PB in maize systems (Parihar et al., 2016). Compared to the rice-wheat system water saving (82 %) was observed in CA-based maize-wheat system (IIMR 2019). Substitution of rice with maize (MW system) recorded 19.7% higher productivity, saved 84.5% of irrigation water and increased net returns by 48.9% compared to farmer's practice (Jat et al., 2019).

CA and soil health in maize systems

A long-term study was conducted to evaluate the tillage practices of ZT, PB and CT in four diversified intensive maize-based crop rotations MWMb, MCS, MMuMb and MMS). In this study, the SOC, physical and biological properties of soil at various depths after were analyzed 7 years of continuous ZT, PB and CT in diversified maize rotations (Parihar et al., 2016a). Compared to CT plots, the soil physical properties like water-stable aggregates (WSA) > 250 mm were 16.1-32.5% higher, and bulk density (BD) and penetration resistance (PR) showed significant ($P < 0.05$) decline (11.0–14.3 and 11.2–12.0%) in ZT and PB plots at 0–15 and 15–30 cm soil layers. The soil organic carbon (SOC) increased by 34.6-35.3% at 0–15 cm, and 23.6-26.5% at 15–30 cm soil depths with conservation agriculture (ZT and PB) based crop establishment techniques over CT. Similarly, the soil microbial biomass carbon (MBC) under CA-based systems increased by 45–48.9% in 0–30 cm profile depth of a sandy loam (Typic Haplustept) soil. Significant ($P < 0.05$) improvement in soil enzymatic activities i.e., Fluorescein diacetate, dehydrogenase, b Glucosidase and Alkaline phosphatase were also recorded in the CA-based treatments. Significant ($P < 0.05$) synergistic effects of summer legumes (mungbean and *Sesbania*) with winter legume/cereal in crop rotations were observed on SOC, WSA, BD, PR and Ksat at 0–15 and 15–30 cm depths. Interaction between tillage and crop rotations were significant ($P < 0.05$) for soil organic carbon, physical properties and enzymatic activities. Thus, this long-term study suggests that CA-based crop management with selected diversified maize-based rotations (MCS and MWMb) can be advocated as sustainable intensification strategy in light-textured soils of north-western India and other similar agro-ecologies of South Asia.

After 6 years, a significant positive effect of CA practices on soil organic carbon (SOC) content, labile SOC fractions, soil microbial biomass carbon and dehydrogenase activity (Parihar et al., 2018). ZT and PB increased SOC stock (0–30 cm depth) by 7.22–7.23 Mg C ha^{-1} whereas CT system increased it only by 0.88 Mg C ha−1as compared to the initial value (Parihar et al., 2018a). In this study, global warming potential (GWP) under CT system was higher by 18.1 and 17.4%, compared to CA-based ZT and PB, respectively. Retention of crop residue in PB increased total SOC by 11.5 to 19.5% compared with PB-R, across the soil depths (Jat et al., 2019b).

Precision Nutrient management in the context of CA

The layering of CA-based management practices with precision nutrient prescriptions using SSNM based decision support tools offers a new management paradigm for scaling up of the MW system in north-west India (Parihar et al., 2017). The adoption of conservation tillage (ZT/PB) practices with improved nutrient management (SSNM/Ad-hoc) could be a viable option for achieving higher productivity, water and energy-use efficiency and profitability in MWMb system. Significantly higher pooled bio-energetic yields (22-35%), net returns (31-38%) and water-use efficiency (30-35%) was observed in SSNM/Ad-hoc plots compared with FFP (farmers fertilizer practices) (Parihar et al. 2017, 2017a). The application of the 33% basal nitrogen followed by green seeker guided N application (33+GS) in maize significantly increased the grain yield of kharif maize by 6.9% over the traditional three splits recommended N application (IIMR, 2019).

Neem coated urea (NCU) has been found suitable to increase N use efficiency and profitability in CA-based maize systems (Jat et al., 2019a, 2019b, 2019c). Field experiments were conducted to evaluate the relative performance of NCU vis-à-vis ordinary prilled urea applied to maize, wheat and mustard The application of NCU at recommended rate (150 kg N/ha) produced significantly higher maize grain yield (7.0 %); NCU @ 120 kg N/ha resulted in significantly higher wheat grain yield (12.3%) and NCU @ 90 kg N/ha resulted in significantly higher mustard seed yield (2.4%) than the yield obtained with ordinary urea on a coarse-textured sandy loam soil. The higher grain yield with the application of NCU over ordinary urea was accompanied by a spectacular increase in nitrogen use efficiencies.

Precision water management in CA

In contrast to conventional till RW rotation which consumed 1889 mm ha^{-1} irrigation water (2-yr mean), CA with sub-surface drip irrigation system saved 58.4 and 95.5% irrigation water in rice-wheat and maize-wheat rotations, respectively. CA with sub-surface drip irrigation in MW systems recorded 5% (2-yr mean) higher profitability with 80% subsidy on installing a sub-surface drip irrigation system and similar profitability without subsidy scenario compared with their respective flood irrigated CA-based systems (Jat et al., 2019). This CA with drip irrigation in maize-wheat system improved energy productivity by 169% and partial factor productivity of N by 49.6% respectively compared to conventional rice-wheat system. The sub-surface drip irrigation system saved the fertilizer N by 20% under CA systems.

Future thrust

There is needed to make small-scale machineries for seeding under CA in maize systems for small and marginal farmers for its enhanced adoption. The good post mergence herbicides (tembotrione, topramezone) available should be demonstrated in maize systems. The making of small videos in the vernacular languages about practices and potential benefits of CA needs to be made on maize systems and made available in social media for its enhanced adoption. The activities of the soil fauna and microbes are not well documented in CA based maize systems that needs to be explored. The enhanced yield responsible microbial consortia in CA can be an important input in agriculture that needs due attention for extending its benefits. The insect and disease dynamics and specially the potential threat if any also need to be studied in details for making it more sustainable. The weed bank seed dynamics is important in CA for making future plausible decisions on out-scaling CA.

The strengthening of the component crop management practices will help in enhancing its adoption owing to more benefits and making it as CA+. Thus, the research evidence suggested that conservation agriculture-based management practices in maize systems have the potential for enhancing crop yield, resource use efficiency, profitability and soil health and these need to be out-scaled appropriately for sustainable maize systems in India and similar ecologies with the best bet input management practices.

References

IIMR (2017). IIMR Annual report 2016-17. ICAR-Indian Institute of Maize Research, Ludhiana.

IIMR (2019). IIMR Annual report 2018-19. ICAR-Indian Institute of Maize Research, Ludhiana.

Jat HS, Sharma PC, Datta A *et al.* (2019) Re-designing irrigated intensive cereal systems through bundling precision agronomic innovations for transitioning towards agricultural sustainability in North-West India. *Scientific Report* **9:** 17929. https://doi.org/10.1038/s41598-019-54086-1.

Jat ML, Dagar JC, Sapkota TB, Singh Y, Govaerts B, Ridaura SL, Saharawat YS, Sharma RK, Tetarwal JP, Jat RK, Hobbs, H and Stirling C (2016) Climate Change and Agriculture: Adaptation Strategies and Mitigation Opportunities for Food Security in South Asia and Latin America. *Advance in Agronomy* **137**:127-236.

Jat SL, Parihar CM, Singh AK, Nayak HS, Meena BR, Kumar B, Parihar MD and Jat ML (2019a) Differential response from N sources with and without residue management under conservation agriculture on crop yields, water-use and economics in maize-based rotations**.** *Field Crops Research,* **236** (2019) 96–110.

Jat SL, Parihar CM, Dey A, Nayak HS, Ghosh A, Parihar MD and Parihar N (2019b). Dynamics and temperature sensitivity of soil organic carbon mineralization under medium-term conservation agriculture as affected by residue and nitrogen management options. *Soil and Tillage Research*. **191**: *https://doi.org/10.1016/j.still.2019.02.005*

Jat SL, Parihar CM, Singh AK, Kumar B, Choudhary M, Nayak HS, Parihar MD, Parihar N and Meena BR (2019c). Energy auditing and carbon footprint under long-term conservation agriculture-based intensive maize systems with diverse inorganic nitrogen management options. *Science of the Total Environment* **664** (2019): 659-668. https://doi.org/10.1016/j.scitotenv.2019.01.425.

Parihar CM, Jat SL, Singh AK, Datta A, Parihar MD, Varghese E, Bandyopadhyay KK, Nayak HS, Kuri BR and Jat ML (2018) Changes in carbon pools and biological activities of a sandy loam soil under long-term conservation agriculture and diversified cropping systems. *European Journal of Soil Science* September 2018, 69: 902–912. *doi: 10.1111/ejss.12680.*

Parihar CM, Parihar MD, Sapkota TB, Nanwal RK, Singh AK, Jat SL, Nayak HS, Mahala DM, Singh LK, Kakraliya SK, Stirling CM and Jat ML (2018a) Long-term impact of conservation agriculture and diversified maize rotations on carbon pools and stocks, mineral nitrogen fractions and nitrous oxide fluxes in Inceptisol of India. *Science of the Total Environment* 640–641:1382-1392.

Parihar CM, Jat SL, Singh AK, Ghosh A, Rathore NS, Kumar B, Pradhan S, Majumdar K, Satyanarayana T, Jat ML, Saharawat YS, Kuri BR and Saveipune D (2017) Effects of precision conservation agriculture in a maize-wheat-mungbean rotation on crop yield, water-use and radiation conversion under a semiarid agro-ecosystem. *Agricultural Water Management*, **192**: 306-319. 10.1016/j.agwat.2017.07.021.

Parihar CM, Jat SL, Singh AK, Kumar B, Yadvinder-Singh, Pradhan S, Pooniya V, Dhauja A, Chaudhary V, Jat ML, Jat RK and Yadav OP (2016) Conservation agriculture in irrigated intensive maize-based systems of north-western India: Effects on crop yields, water productivity and economic profitability. *Field Crops Research* **193**:104-116. Doi: doi:10.1016/j.fcr.2016.03.013

Parihar CM, Jat SL, Singh AK, Majumdar K, Jat ML, Saharawat YS, Pradhan S and Kuri BR 2017a. Bio-energy, water-use efficiency and economics of maize-wheat-mungbean system under precision-conservation agriculture in semi-arid agro-ecosystem. *Energy* **119**: 245-256. DOI: 10.1016/j.energy.2016.12.068.

Parihar CM., Yadav MR, Jat SL, Singh AK, Kumar B, Pradhan S, Chakraborty D, Jat ML, Jat RK, Saharawat YS and Yadav OP (2016a). Long term effect of conservation agriculture in maize rotations on total organic carbon, physical and biological properties of a sandy loam soil in north-western Indo-Gangetic Plains. *Soil and Tillage Research* **161**: 0167-1987. doi:10.1016/j.still.2016.04.001.

Oral Presentations

OP-1. TEOSINTE ALLELIC INFLUX AS A MEASURE TO ENHANCE AND STRENGTHEN DIVERSITY IN MAIZE

Singh N.K., Adhikari S., Joshi A. and Sahoo S.
G. B. Pant University of Agriculture and Technology, Pantnagar
narendraksingh2@gmail.com

Being a wild grass in nature, Teosinte has contributed significantly in supporting economy, employment, food and feed requirement of the society across the continents through evolving maize-the highest yielding cereal grain. Domestication followed by artificial selection completely transformed teosinte into a plant architecture morphologically widely divergent from progenitor teosinte. This happened probably because of the selective breeding and artificial selection of few hundred of genes responsive to favourable environmental conditions. Consequently, genetic yield potential of maize has increased tremendously on the one hand but on the other hand consequences of domestication and breeding bottlenecks were realized in the form of limited genetic diversity in cultivated maize when compared with diversity in wild relatives of maize. Recapitulation of allelic diversity, which probably lost during the domestication and selective breeding, through teosinte genomic influx is therefore seems to be essential to ensure sound diverse genetic base for maize improvement programme. Considering preceding facts and prospects in mind, maize inbred line was crossed with teosinte, the resulting F1s were backcrossed with maize followed by four generation of selfing to generate BC1F5 population consisted of 169 lines and were evaluated during *kharif* 2018. Analysis of variance revealed significant differences for all the characters indicating diverse nature of individuals of the BC1F5 population. Days to anthesis, silking and ASI were varied from 47-68, 44-67 and (-) 4-5 days in BC1F5 whereas the same were 52.5, 54.5, 2.5 and 81.5, 78 and (-) 3.0 days in maize and teosinte, respectively. In teosinte and maize height of the plants were 242 and 97.4 cm whereas in BC1F5 lines, it varied from 88-229.3 cm. One to five ears/plant were noted in BC1F5 lines whereas in maize and teosinte, the same was 1 and 242 on average. Ear length and diameter were greatly modified and a range of 3.16-19.16 cm and 0.81-7.16 cm, respectively were observed. Kernel rows/ear and kernels/row were varied from 2.66-16.0 and 3.5 -44.8, respectively. Similarly, for other traits namely flag leaf length, flag leaf width, node bearing first ear, test weight and grain yield/plant, wide range of variations was observed in BC1F5 population. In addition, variations were also observed for anthocyanin colouration of leaf sheath, glumes and anthers, angle between leaves and stem and tassel length. The observations of the investigation therefore indicate diversification of maize germplasm for different characters. Variation for male and female flowering behavior and angle between stem and leaf are seems to be the important allelic introgression and may help in increasing adaptability and productivity of maize. However, introgression of some undesirable features namely loose husk requires strategic intervention to filter out the beneficial alleles from teosinte.

OP-2. GENETIC ANALYSIS, IDENTIFICATION OF NOVEL SNPS AND DEVELOPMENT OF MULTI-NUTRIENT MAIZE HYBRIDS THROUGH STACKING THE FAVOURABLE ALLELES OF *O2*, *CRTRB1* AND *VTE4* GENES

Das A.K.[1], Muthusamy V.[2], Zunjare R.K.[2], Chauhan H.S.[2], Jaiswal S.[2], Chhabra S.[2], Baveja A.[2], Chand G.[2], Sharma P.K.[2], Bhat J.S.[2], Guleria S.K.[3], Saha S.[2] and Hossain F.[2]
[1]ICAR-Indian Institute of Maize Research, PAU campus, Ludhiana
[2]ICAR-Indian Agricultural Research Institute, New Delhi
[3]CSK-Himachal Pradesh Krishi Vishwavidyalaya, Bajaura
das.myself@gmail.com

Micronutrient deficiency affects two billion people worldwide. Vitamin-E (α-, β-, γ- & δ-tocopherol) is a major antioxidant and essentially required for cardiovascular- and neurological- functions in humans. α-tocopherol has the highest vitamin-E activity but present in low proportion in maize kernel. Most favourable haplotype (0/0) of *VTE4* having deletions of 7bp and 118bp accumulates more α-tocopherol than wild type (7/118). Multilocation evaluation of 54 maize inbred revealed wide genetic variation for α-tocophrol (3.24-28.63µg/g), γ-tocopherol (3.50-52.41µg/g) and total tocopherol (16.40-87.67µg/g). Higher proportion of α-tocopherol/ total tocopherol among favourable classes was observed than unfavourable class. Testcross analysis of 36 hybrids (9 × 4) revealed the prominence of non-additive gene action for α-, γ-and total-tocopherol and additive gene action for δ-tocopherol. AMMI analysis revealed that genotype and interaction effect accounted 35-77% and 23-45% of variation, respectively across tocopherols. Sequence analysis of promoter and 5'UTR in *VTE4* gene among 15 inbreds identified 14 new SNPs and eight InDels of which SNP7, InDel1, InDel4 and InDel8 could differentie low and high α-tocopherol accumulating inbreds with favourable haplotype. Further, the favourable allele (0/0 haplotype) of *VTE4* was introgressed through marker-assisted backcross breeding in the background of provitamin-A rich QPM (high lysine and tryptophan) inbreds (HKI161-PV, HKI163-PV, HKI193-1-PV and HKI193-2-PV). Mean α-tocopherol (16.62 µg/g, 14.23 µg/g, 16.11µg/g and 14.24 µg/g) and mean α-tocopherol/ total tocopherol ratio (43%, 78%, 25% and 29%) was significantly increased in the introgressed progenies of HKI161-PV, HKI163-PV, HKI193-1-PV and HKI193-2-PV, respectively. Selected BC_2F_2 derived inbreds recorded recovery of >90% of recurrent parent genome. During the selection, favourable allele of *opaque2*, *crtRB1* and *lcyE* present in the original lines were also retained. The multi-nutrient rich maize inbreds with high lysine, tryptopha, provitamin-A and vitamin-E assume to be of great significance in alleviating malnutrition through sustainable and cost-effective approach.

OP-3. PARASITISM CAUSED BY *TRICHOGRAMMA CHILONIS AND COTESIA FLAVIPES* AGAINST *CHILO PARTELLUS*

Singh B., Mahla M.K., Chhangani G. and Vyas A.K.
Maharana Pratap University of Agriculture and Technology, Udaipur
bsgento95@gmail.com

The Egg parasitization by *Trichogramma chilonis* in the maize stem borer (*Chilo partellus*) eggs were released in maize crop at 15, 22 and 29 days after germination during July – December 2019 at the Department of Entomology, Rajasthan College of Agriculture, MPUAT, Udaipur. The eggs were exposed to natural parasitization by *T. chilonis* and were collected back to record parasitization and emergence of *T. chilonis*. The number of adults emerged from parasitized eggs ranged from 64 to112 adults/ replication. The maximum number of adults emerged (124 & 128) at 15 days after germination where 230 & 250 eggs of *C. partellus* were released. The minimum number of adults emerged (87) at 29 days after germination from 192 eggs of *C. partellus* were released. Larval parasitization (*Cotesia flavipes*) twenty larvae obtained from infested plants with higher leaf injury rating (LIR) were collected at 15, 22 and 29 days after germination and were reared to record the emergence of larval parasitoid, *C. flavipes*. The numbers of parasitized larvae were 7, 9 and 8 at 15, 22 and 29 days after germination respectively. The per cent larval parasitization recorded was 35, 45 and 40 at 15, 22 and 29 days after germination. The number of cocoon recorded was 58, 64 and 63 at 15, 22 and 29 days after germination respectively. The parasitoid *C. flavipes* was found to parasitize the *C. partellus* in field conditions.

OP-4. GENOME WIDE ASSOCIATION MAPPING FOR HEAT TOLERANCE IN SUB-TROPICAL MAIZE

Longmei N.[1], Gill G.K.[1], Zaidi P.H.[3], Kumar R.[4], Nair S.K. [3], Vemuri H.[3], Vinayan M.T.[3] and Vikal Y.[2]

[1]Plant Breeding and Genetics, [2]School of Agricultural Biotechnology, Punjab Agricultural University, Ludhiana

[3]International Maize and Wheat Improvement Centre, Asia Regional Office, Hyderabad

[4] ICAR-Indian Institutes of Maize Research, Ludhiana

Heat tolerance is becoming increasingly important where maize is grown under spring season in India which coincides with grain filling stage of crop resulting in drying of tassel tissue (tassel blast), reduced pollen viability, pollination failure and barren ears that causes devastating yield losses. So, there is need to identify the genomic regions associated with heat tolerance component traits which could be further employed in maize breeding program. An association mapping panel, consisting of 662 doubled haploid (DH) lines derived from nine bi-parental pedigree populations and test-crossed with a heat susceptible tester line (CML-474) was evaluated for yield contributing traits under normal and natural heat stress conditions. Genome wide association studies (GWAS) carried out using 187,000 SNPs and 130 SNPs significantly associated for grain yield (GY), days to 50% anthesis (AD), days to 50% silking (SD), anthesis-silking interval (ASI), plant height (PH), ear height (EH) and ear position (EPO) were identified under normal conditions. A total of 46 SNPs strongly associated with GY, ASI, EH and EPO were detected under heat stress conditions. Fifteen of the SNPs was found to have common association with more than one trait such as two SNPs *viz.* S10_1905273 and S10_1905274 showed colocalization with GY, PH and EH whereas S10_7132845 SNP associated with GY, AD and SD under normal conditions. No such co-localization of SNP markers with multiple traits was observed under heat stress conditions. Haplotypes trend regression analysis revealed 122 and 85 haplotype blocks, out of which, 20 and 6 haplotype blocks were associated with more than one trait under normal and heat stress conditions, respectively. Each of the haplotype block had range of 2 to 21 SNPs. Based on SNP association and haplotype mapping, nine and seven candidate genes were identified respectively, which belongs to different gene models having different biological functions in stress biology. The present study found significant SNPs and haplotype blocks associated with yield related traits, directly or indirectly related to heat stress mechanism, which help in selection of donor lines or lines with favorable alleles for multiple traits. Gene families underlying loci corresponded to functions

ranging from sensing abiotic stresses and regulating plant response such as universal stress protein domain containing protein, expressed protein, chloroplast precursor, stripe rust resistance protein and stomatal closure. These results provide fundamental information for understanding the genetic basis of heat tolerance. The genomic regions detected in this study need further validation before being applied in the breeding pipelines.

OP-5. EFFECT OF HEAT STRESS AND WATER SCARCITY ON SOME OF THE GROWTH AND DEVELOPMENTAL STAGES OF MAIZE

Nazir A., Bahar F.A., Bhat M.A., Bhat T.A., Dar Z.A., Sheikh T.A. and Bhat R.A.
Division of Agronomy, Faculty of Agriculture,Wadura,
Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir

Maize (*Zea mays* L.) is a globally important staple crop for food, livestock feed and biofuels, even though it is very sensitive to abiotic stresses, including high temperature, which leads to considerable yield loss in crop production. Of the various abiotic stresses such as light intensity, salinity, drought, temperature (freezing/heat) is the most prevalent that considerably retard not only plant production but also the quality of crops. Heat stress is defined as the rise in temperature beyond a threshold level for a period sufficient to cause permanent damage to plant growth and development. The disturbance in cellular homeostasis is due to high temperature stress which can cause drastic reduction in growth, development and even death of plants. The growth and development optimum temperature is specific to each genotype. The temperature stress occurs when the environmental temperature increases beyond the critical limit. Heat stress is responsible for 1.0-1.7% maize yield loss per day, for every degree rise in temperature above 30^{o}C. The stages of maize growth are differently affected by high temperature stress. Heat stress during germination is associated with impaired emergence, reduced plant stand and plant density. Maize plants usually develop different mechanisms to counteract the environmental stresses. They need to adapt quickly to overcome these stresses during their short life cycle. With the general warming of the world, developing cultivars of maize that can perform well under heat stress, drought stress and combined heat and drought stress should be taken into consideration. The tolerance of plants to a combination of different stress conditions, especially those that mimic the field environment should be the focus of future research. Water plays a vital role in the survival of plants as it is universal solvent, transport medium and evaporative coolant as well as providing the energy to drive photosynthesis, the natural plant process that synthesize organic food. Under moisture stress condition, the loss of water in the plant protoplasm results in the concentration of ions in the protoplasm to toxic levels resulting in possible protein degradation and membrane fusion and negatively impacting plant metabolism. Moisture stress is one of the major constraints in maize productivity. Out of the total area for maize cultivation about 4.0 million hectares are prone to drought in India as 80% of the India in Kharif season is rainfed. Moisture stress is very common in the areas where maize is predominantly grown under rainfed conditions. Whether in India or elsewhere in the world generally in rainfed areas rainfall is either unpredictable or uneven distribution. The crop is particularly sensitive to water stress in the period one week before and two weeks after flowering. Moisture stress during this period results in an increase in the anthesis silking interval (ASI) and grain abortion. Tassel blasting can occur in maize if drought coincides with high temperature. Remobilization of stem reserves can occur, when stress coincides with the phase of linear grain growth. In extreme cases this can result in premature lodging. Single cross hybrids have better tolerance due to its inherent genetic capacity to cope better in the drought than other OPV's and composites.

OP-6. EFFECT OF CLIMATE CHANGE ON MAIZE DISEASES AND THEIR STATUS IN RAJASTHAN

Sharma S.S.[1], Yadav K.[1], Khokhar M.[1] and Sarita[2]
[1] Rajasthan College of Agriculture, Maharana Pratap University of Agriculture and Technology, Udaipur
[2]ICAR-National Research Centre for Integrated Pest Management, New Delhi

Rajasthan is the state where, maximum maize is being grown and having largest area under cultivation. There has been a taboo that maize is considered as prime staple food. There is another bottleneck that maize is being cultivated under rain fed conditions which has more than 68 % area. Assured irrigation is limited. The average productivity is less than the national average. The crop has been challenged by several pathogens and dominant are fungal ones. Post Flowering stalk rot is major disease caused by *Fusarium verticillioides* and bacterial association also. This is called as rot complex. This causes more than 38 % losses in yield followed by Banded leaf and sheath blight which causes more than 70% losses. Banded leaf and sheath blight is more prominent where rice- maize pattern is seen. The sheath blight pathogen *Rhizoctonia solanii* is same. Foliar pathogens like Curvularia leaf spot (*Curvularia lunata*), Maydis leaf blight (*Bipolaris maydis*) and one systemic pathogen Rajasthan Downey mildew (*Peronosclerospora heteropogonii*) are also causing severe damage. The climate change is causing many diseases to be severe and some are moderate. The change is rainfall pattern and rise in temperature greatly affecting the severity of disease. If there is 20 days gap or dry period at flowering, this will cause high severity of PFSR and more foliar pathogens, many a times if the rainfall distribution is not proper it will cause earlier onset of diseases. The pattern of symptoms also changed. Earlier the MLB and CLS used to appear at 50-55 DAS, but now these are occurring at seedling stage. The Rajasthan Downey Mildew is coming on both sides of leaves; otherwise principally it used to be on downy side only. Even there are observations that it also infects the plants at 30 DAS, which are new reports. Overall, the disease scenario is changing due to climate change and five years data has been used to depict the effect which proves the change is relation to aberration in climate.

OP-7. ENDOSPERM MODIFIERS MEDIATED EXPRESSION OF PROLAIM-LIKE FRACTION AND ITS ROLE IN VITREOUS KERNEL DEVELOPMENT IN MAIZE

Sethi M[1], Chaudhary D.P.[2] and Kaur C.[1]
[1]Department of Biochemistry, Punjab Agricultural University, Ludhiana
[2]ICAR-Indian Institute of Maize Research, Ludhiana

Maize kernel texture and protein quality are known to be inversely related to each other. Vitreous kernel texture of maize endosperm is defined by regular starch protein matrix. Zein is the protein fraction which is solely responsible for vitreous kernel texture. Considering protein quality the endosperm protein are broadly classified as nutritionally poor zein (prolamin and prolamin-like) and nutritionally rich non-zein (albumin, globulin, glutelin-like and glutelin). It is well established that protein quality is immensely increased in *opaque-2* mutants due to increase in non-zein fractions over zein, whereas in QPM both protein quality and kernel texture is retained due to introgression of *opaque-2* gene along with endosperm modifiers. The present study was planned to analyse the translational response of endosperm modifiers in QPM, in comparison to normal and *opaque-2* counterparts. The results revealed that among different protein fractions viz: albumin, globulin, prolamin, prolamin-like, glutelin-like and glutelin only prolamin-like fraction was found to be retained maximally in QPM lines (14.91%) in comparison to *opaque-2* (11.76%) and normal (11.88%) lines. Along with it 27 KDa gamma zein was found to be the major prolamin like protein involved in retrieving vitreous kernel texture in QPM background. Overall present study benefits with fact that the significant difference in prolamin-like fraction among normal and QPM lines can be used as a quick marker to analyse visually indistinguishable high and low protein quality lines, so estimation of prolamin-like fraction can act supplementary biochemical marker for analysing developing QPM lines.

OP-8. VALIDATION OF SENSOR BASED NITROGEN MANAGEMENT IN MAIZE IN GODAVARI ZONE OF ANDHRA PRADESH

Sujatha V., Kumar S., Chandra P.B.[2], Singh A.K.[3] and Jat S.L.[4]
[1,2]Agricultural Research Station, Peddapuram, East Godavari Dist.
[3,4] ICAR-Indian Institute of Maize Research, Ludhiana
sujatha.agro12@gmail.com

Precision nitrogen management techniques in maize *viz*., Green seeker optical sensor, Site specific nutrient management (SSNM) through Soil-test crop response (STCR) or Nutrient expert have the potential to increase nitrogen fertilizer use efficiency, productivity, profitability and to reduce losses under changing climate. A Field study was conducted at Agricultural Research Station, Peddapuram, East Godavari Dist. during *kharif,* 2018 on sandy loam soils to evaluate the effect of sensor-based nitrogen application on growth, yield and economics of Maize. The experiment was conducted in RBD with three replications. Treatments consisted of T_1- Control, T_2- RDF (1/3+1/3+/1/3 N splitting at basal, knee high and tasseling), T_3- STCR (1/3+1/3+/1/3 N splitting at basal, knee high and tasseling), T_4 - Nutrient expert (1/3+1/3+/1/3 N splitting at basal, knee high and tasseling), T_5 -33% basal N + Green Seeker based N at knee high & tasseling stage , T_6 -60% basal N + Green Seeker based N at knee high stage , T_7 -70% basal N + Green Seeker based N at knee high , T_8 -60% basal N + Green Seeker based N at tasseling stage , T_9 -70% basal N + Green Seeker based N at tasseling stage , T_{10}- 30% Basal N + 30% at 25 DAS + Green Seeker based N at tasseling stage, T_{11} - 35% Basal N + 35% at 25 DAS + Green Seeker based N at tasseling stage, T_{12} - N rich strip (300:60:40) (1/3+1/3+/1/3 N splitting at basal, knee high and tasseling). Experimental results revealed that the application of 35% Basal N + 35% at 25 DAS + Green Seeker based N at tasseling stage recorded significantly higher grain yield (6114 kg/ha) which was at par with 30% Basal N + 30% at 25 DAS + Green Seeker based N at tasseling stage (5975 kg/ha) and RDF (5647 kg/ha). Similarly, highest net returns and B:C ratio (Rs.47505 /ha & 2.25 respectively) was recorded with 35% Basal N + 35% at 25 DAS + Green Seeker based N at tasseling stage which was at par with 30% Basal N + 30% at 25 DAS + Green Seeker based N at tasseling stage (Rs. 45952/ha & 2.22) and RDF (Rs.40566/ha and 2.05) with nitrogen saving of 33 kg/ha. Based on the present study, It can be inferred that though yield was at par with RDF green seeker based nitrogen application could be a better option in terms of profitability and nitrogen saving in maize. Thus, In future precision nitrogen management using green seeker optical sensor can be successfully used for making site specific in -season fertilizer nitrogen management decisions for maize in Godavari zone of Andhra Pradesh.

OP-9. MODELLING SOIL WATER BALANCE AND CROP WATER USE IN MAIZE UNDER CONSERVATION AGRICULTURE USING HYDRUS-2D

Patra K.[1], Parihar C.M.[1], Rana B.[1], Nayak H.S.[1], Jat M.L.[2], Sidhu H.S.[3], Gupta N.[3] and Singh V.K.[1]

[1]ICAR-Indian Agricultural Research Institute, New Delhi
[2]International Maize and Wheat Improvement Centre, New Delhi
[3]Borlaug Institute for South Asia, CIMMYT, Ludhiana
kiranmoypatra7@gmail.com

In the conventional tillage system (CT), repeated tillage and burning of crop residue are the two major causes of concern for soil health deterioration and environmental pollution; the key indicators of sustainability. Conservation agriculture (CA) based new innovative agronomic management practices like zero-tillage flat (ZT), permanent beds (PB), residue recycling, precision water and nutrient management etc. have been used as an alternative to CT. Therefore, to improve crop productivity and farmers' profitability and looking to the constraints of water shortages in future, it is imperative that we have to put more efforts on re-designing/diversify rice based systems through developing efficient and remunerative CA-based practices for increasing water productivity and farmer's profitability in north-western (NW) Indo-Gangetic Plains (IGP). Further, substitution of high water requiring crops with low water requiring crops like maize, can maximize productivity under water limited environments (Reddy and Suresh, 2008). Therefore, in the RW system dominated resource degraded zone of IGP, for future sustainability and food security the feasibility of upcoming crop like maize. Worldwide maize is the third important cereal grown over 150 nations and In India it is cultivated in 8.6 m ha (2.2%) (Ranum et al., 2014). Being C_4 crop maize has better adaptation to climate change. Maize cultivation became profitable with the advent of single cross hybrids (SCHs) with high yielding potential. Further, SCHs maize with CA-based practices have twin benefit of improvement in crop productivity *vis a vis* soil health and is a possible alternative to rice in rice-wheat system in IGP. Irrigating the crop plant with drip system can tackle the water scarcity problem and can enhance the water use efficiency. Although many researchers (Sidhu et al., 2019) have reported higher crop productivity and less water use under sub-surface drip irrigation (SSDI) system, but the information accounting the complete soil water balance in high water requiring crop like rice grown under SSDI in CA are not available. Mathematical simulation is essential for partitioning the soil water into various input (Rainfall and initial soil moisture) and output (RWU, evaporation and drainage) components to reckon the soil water balance (SWB) (Parihar et al., 2019). In this scenario the soil hydrological process based model Hydrus-2D (Šimůnek et al., 2008) was used to simulate the two-dimensional movement of water by using Richard's equation for unsaturated flow in different soil layers and to estimate each component of the soil water balance. In our study on maize, daily root water uptake (cm) of SSDI150N +R treatment was highest followed by SSDI150N-R, CT 120N, ZT 120N, SSDI 0N+R, SSDI 0N-R during the entire simulation period of 43 days. Across the sub-surface drip and nitrogen application treatments in maize under CA-based maize the cumulative evaporation followed the trend: SSDI150N +R< SSDI150N-R< ZT120N< CT120N< SSDIN0-R< SSDIN0+R.The cumulative deep drainage (CDD) was highest in SSDI control treatment (SSDI N0-R) because of lower crop growth and development and subsequently less water use.

OP-10. A STUDY ON EARTHWORM POPULATION AND MICROBIAL ACTIVITY IN THEIR CASTS IN LONG-TERM TILLAGE AND RESIDUE MANAGEMENT PRACTICES

Kumar N.[1], Suby S.B.[1], Parihar C.M.[2], Jat S.L.[1], Gambhir G.[1]and Rakshit S.[1]
[1]ICAR-Indian Institute of Maize Research, Delhi Unit, New Delhi
[2]ICAR-Indian Agricultural Research Institute, New Delhi
subysb@gmail.com

Earthworms are very important organisms in improving the soil biophysical properties by their action of burrowing and cast production (Lavelle 2001). Therefore, the present study was carried out to study the effects of varying tillage practices [Permanent bed (PB), Zero tillage (ZT) and Conventional tillage (CT)] and cropping systems [Maize- wheat-Mungbean (MWMb), Maize-Chickpea-sesbania (MCS), Maize-Mustard-Mungbean(MMuMb) and Maize-Maize-Sesbania (MMS)] on earthworm population and fertility of earthworm casts (EC). This study was undertaken in a long term experiment going on at fixed site since 2008. The number of earthworm was observed in *kharif* season 2019 after digging soil 20x 20 x20 cm and number of EC was observed using a square meter quadrant at three random sites per replications at flowering stage. Number of earthworm is higher in zero tillage system and best system irrespective of the tillage was MWMb. The above observations were also reflected in EC counts. Fertility of EC indicated by its biological activity in terms of assays viz., fluorescein diacetate (FDA) hydrolysis, urease and alkaline phosphatase (APA) which were found to be significantly higher in EC than the bulk soil taken from 0-15 cm depth, while the beta glycosidase activity was observed to be non significant between soil and EC. The EC has 2.1 times FDA (15.49 µg Florescein g^{-1} h^{-1}), 1.33 times APA (174.14 U / gram of dry soil) and 1.09 times urease activity (141.85 µg NH4-N-g-1 dwt $2h^{-1}$) than surrounding soils. Further there was no significant difference between the fertility of EC from the different tillage and cropping systems. Since fertility of EC remains constant irrespective of the environment, the variation in number of casts/earthworms in tillage system plays the major role in soil fertility.

OP-11. DEVELOPMENT OF HIGH QUALITY READY TO EAT MAIZE EXTRUDATES

Kaur N[1], Singh B.[1], Kumar R.[2] and Sharma S.[1]
[1]Department of Food Science and Technology, Punjab Agricultural University, Ludhiana
[2]ICAR- Indian Institute of Maize Research, Ludhiana

navjot1667@gmail.com

The present research was carried out to explore the utilization of quality protein maize to prepare nutritious extruded snacks because of its superior protein quality due to the presence of two essential amino acids that is lysine and tryptophan. The effects of extrusion process variables such as screw speed (400– 550 rpm), barrel temperature (125–175°C) and feed moisture content (14-18%, on dry basis) on the system and functional properties of normal and quality protein maize based snack product were studied. The experiment was executed using central composite design (CCD) in response surface methodology (RSM). Regression analysis of experimental data revealed the significant effects of screw speed followed by feed moisture content and barrel temperature on functional properties of extrudates ($p \leq 0.01$ and $p \leq 0.05$). The optimal extrusion process parameters obtained were feed moisture content 14.01-15.69%, 14.22-14.96% and barrel temperature 138.28-172.37ºC, 168.90-175ºC at 475 rpm screw speed for normal and quality protein maize, respectively.

OP-12. NUTRITIOUS MULTIGRAIN *CHAPATTI* FOMULATION INCORPORATING QUALITY PROTEIN MAIZE FLOUR

Kaur J. and Kaur A.
Department of Food Science and Technology, Punjab Agricultural University, Ludhiana
jaspreet@pau.edu

Quality Protein Maize (QPM) has excellent potential as a nutritious ingredient in bakery formulations to supplement wheat flour due to its superior protein quality and high content of bioactive components such as dietary fibre. Multigrain *chapatti* formulation was standardized by supplementing whole wheat-oat flour blend (20 per cent oat) with QPM and soybean flours. Whole wheat was replaced with QPM and soybean at 5, 10, 15 and 5 and 10 per cent levels, respectively. Whole wheat *chapatti* was used as control. Water absorption of the blends significantly ($P \leq 0.05$) increased with increase in QPM and soybean flours. Sensory characteristics, *viz*., appearance, flavor and mouthfeel varied significantly ($P \leq 0.05$) with QPM and soybean flour incorporation. Crude fat and crude fibre contents of whole grain *chapatti* increased significantly ($P \leq 0.05$) with addition of QPM and soybean flours. There was a significant ($P \leq 0.05$) improvement in physiological functionality of whole grain *chapatti* higher antioxidant activity (per cent DPPH inhibition) and total phenolic content. This multigrain *chapatti* formulation can be used as a nutritious and functional food for preventing several chronic diseases such as diabetes and cardiovascular disorders.

OP-13. EVALUATION OF MAIZE VARIETIES POTENTIAL FOR FORAGE YIELD, SILAGE QUALITY TRAITS AND NUTRIENT UPTAKE IN CENTRAL GUJARAT CONDITIONS

Singh D. and Choudhary A.
National Dairy Development Board, Anand
dsingh@nddb.coop

An experiment was conducted at fodder demonstration unit (FDU) of National Dairy Development Board, Anand (Gujarat) during two seasons i.e. *Kharif* 2016 and *Zaid* 2017 to evaluate the performance of 13 popular maize varieties J-1006, Narmada Moti, Pratap Makka Chari-6 (PMC-6), African Tall , P-3502, P-31Y45, Rajshri, Pratap Hybrid Maize-3 (PHM-3), Gujarat Anand Yellow Maize Hybrid-1 (GAYMH-1), Gujarat Anand White Maize Hybrid-2 (GAWMH-2) and High Quality Protein Maize-1 (HQPM-1). Maize variety African Tall (AT) was found superior in terms of green fodder yield (35.19 t/ha), plant height (265.13 cm), stem-thickness (16.58 cm), number of leaves per plant (13.87) and nitrogen uptake (145.34 kg/ha). African Tall, PMC-6, P-3502 and PHM-3 yielded over 30 t/ha green fodder which was higher than local check GAYMH-1. Statistical difference for dry matter yield (DMY) were found non-significant but more than 8 t/ha DMY was recorded in PMC-6, AT and P-3502. Overall in trial, DMY varied from 6.54 t/ha to 8.91 t/ha. In the trial, crude protein yield (CPY) varied significantly from 0.54 t/ha to 0.84 t/ha. P-3502 recorded highest crude protein yield (8.14 t/ha) and Mg content (0.56%) while Rajshri was superior in terms of brix (8.83%) and sulphur (0.13 %). Highest phosphorus was found in J-1006 (0.29%) and highest calcium uptake was recorded in maize variety PMC-6 (28.60 kg/ha). Maize variety PHM-3 recorded higher P_2O_5 uptake (51.16 kg/ha), K_2O uptake (79.45 kg/ha) and copper content (63.71ppm). Brix % in stem juice of maize varieties significantly varied from 6.19 to 8.83. Significantly lower pH was recorded in silage of maize variety PMC-6 (3.78) but statistically at par with maize hybrids HQPM-1 (3.86), GAWMH-2 (3.89), GAYMH-1 (3.91), P-31Y45 (3.95) and PHM-3 (3.98). In silage of maize varieties mean pH, dry matter, crude protein, ether extract, crude fibre, silica content ranged between 3.78-4.27, 24.77-27.57 %, 8.71-10.69 %, 1.02-1.59 %, 28.86-31.66 % and 3.27-4.40 %, respectively. Zn, Mn and Fe content in maize varieties was recorded between 20.00-28.90 ppm, 38.56-57.89 ppmand 725.00-1063.08 ppm, respectively however statistical differences were found to be non-significant. Amongst maize varieties, nitrogen (N) and P_2O_5 uptake varied significantly from 98.40 kg/ha to 145.34 kg/ha and 30.46 to 51.16 kg/ha, respectively. Trial results indicated that both maize varieties (forage type composite and grain hybrids) are potentially excellent source of nutritious green fodder free from any anti-nutritional component. Better green fodder production was observed in maize composites African Tall & PMC-6 and grain hybrids P-3502 & PHM-3 with yield over 30 t/ha green fodder and more than local check GAYMH-1. Quality traits, macro and micro nutrient concentrations in silage of forage and grain type maize varieties were present in desirable quantities.

OP-14. MAIZE AS A CHIEF SOURCE OF QUALITY FEED AND FODDER FOR INTENSIFIED AND SUSTAINABLE LIVESTOCK HUSBANDRY IN KARNATAKA

Mahadevu P., Lohitashwa H.C., Shekara B.G., Shobha D., Mallikarjuna N., Jadesha G., Ravindrababau B.T., Chikuragi N., Shivakumar B.S., Manasa N. and Swapna G.

AICRP on MAIZE and AICRP on Forage crops and utilisation, Zonal Agricultural Research Station, Mandya, UAS, Bangalore

Karnataka is one of the leading states of maize cultivation for multipurpose with higher growth in area, production and productivity as compared to other states due to diversified maize production systems. Livestock sector in Karnataka is contributing significantly to the total agriculture GDP of the state. Increased demand for processed dairy, poultry and meat will in turn demand for high feed requirement. Maize is grown for grain, baby corn, green cob and green fodder purposes. The stay green hybrids developed in the state playing key role in providing both grain and green fodder as dual purpose crop. Farmers around cities venturing for maize cultivation for baby corn, sweet corn and fodder maize production on commercial scale in order to meet ever growing demand for quality green fodder and silage in intensified livestock production including dairying, sheep and goat rearing. Bridging the gap between demand and supply of green and dry fodder and feed for livestock is required for achieving higher growth rate and crop diversification for livestock based farming systems in which maize play a key role in fulfilling both quantity and quality feed and fodder. Availability of quality protein maize hybrids with enriched micro nutrients for poultry and animal husbandry is an important option for enhancing the productivity and quality.

OP-15. ADOPTION OF MAIZE FODDER PRODUCTION TECHNOLOGIES BY SMALLHOLDER DAIRY FARMERS IN BARNALA DISTRICT OF PUNJAB

Singh S., Tanwar P.S. and Verma H.K.
Krishi Vigyan Kendra, Barnala, DEE, Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana
suryendra_aligarh@yahoo.com

This study examined adoption of maize fodder production technologies by smallholder dairy farmers (Having 5-7 animals) in Barnala District of Punjab. A pre-formulated questionnaire was used to collect data. Multi-stage sampling procedure was employed where a total of 100 smallholder dairy farmers were selected randomly. Descriptive and inferential statistics were used for data analysis. Dairy farmers' adoption index indicated relatively high scale adoption of HYVs (67.00%) and seed rate (57.00%) by the majority of farmers. The relatively low adopted production technologies by the majority of farmers were plant protection (79.00) and manuring and fertilizer application (68.00%). Irrigation (73.00%) and weed (69.00%) management practices recorded majority on medium scale basis. The study identified constraints which include high cost of seed and other inputs. Tobit multivariate regression model results indicated age, education, herd size and participation in extension activities were significant ($P \leq 0.01$) determining factors influencing adoption of maize fodder production technologies. Adoption of maize fodder production technologies will be sustainable amongst smallholder dairy farmers, if the constraints are overcome. Therefore, it is recommended that the extension agencies give priority to develop strategies and programmes for smallholder dairy farmers especially for maize fodder production.

OP-16. CONTRIBUTION OF PUBLIC AND PRIVATE HYBRID MAIZE IN MADHYA PRADESH

Khanorkar S.M.[1] and Paradkar V.K.[2]
[1]Retd. Head & Professor/Research Scientist, Anand Agricultural University, Anand
[2]AICRP on Maize, Zonal Agricultural Research Station, Jwahar Lal Nehru Krishi Vishwa Vidyalay, Chhindwara

aicrpagrorewa@gmail.com

Maize is grown in 8.71 million ha area with production of 25.90 million MT and yield 2556 kg/ha in India (Anonymous, 2016-17). The yield is strikingly low as compared to that of the USA, where the yield has reached up to 10.7 MT/ha with less than half of acreage under maize cultivation as compared to the area under cultivation in the country. Argentina and Ukraine are also able to produce more than double the yield of Indian. It is cultivated in Meghalaya, western Uttar Pradesh, Haryana, Punjab, Maharashtra, Karnataka and Andhra Pradesh, hill ecologies *viz.,* North Eastern Himalayas like, Uttarakhand, Jammu and Kashmir and Himachal Pradesh and rainfed tribal states like, Madhya Pradesh, Chhattisgarh, Rajasthan, Gujarat and Odessa. The large area of rainfed tribal is still remained untreated with recommended dose of fertilizers under the crop production. The current maize production scenario highlights presence of hybrid maize at about 65-70 percent acreages and most of it accounts for animal and poultry feed and maize based industry. The food grade maize is produced by using traditional cultivars (OPVs). In the recent years, although the rate of adoption of hybrids observed to be slow down, but farmers continues to replace traditional cultivars/old hybrids by improved and high yielding hybrids in the state. In Madhya Pradesh, the hybrid cultivation observed to be 68.0 % in *Kymore* plateau and Satapura hills and Satpura plateau (Domain -1), 73.0 % in Malwa and Vindyan plateau (Domain- 2) and 65.0 % in Jhabua hills (Domain -3) during 2014-15. Since then, it is becoming increased to meet demands of consumers and profitable to the farmers than other cereal, pulses and oilseed crops under climate change environment. The state showed cultivation of 25.0 % composite varieties released by AICRP on Maize, JNKVV, Chhindwara including Gujarat state and 6.4 % local OPVs especially, in tribal belt for food purpose and ethnic belief. The marginal and poor resources farmers of this belt do not take risk to cultivate hybrids and used early maturing landraces and OPVs recommended by AICRP centers of Central Western Zone for food and feed security in their livelihood. There is a widespread realization that farm mechanization is indispensable for increasing yield. While we aim to double the yield of Maize by 2022, intervention of mechanization in maize is crucial. Shortage of farm labour, need for timely farming operations and the need to increase productivity has seen mechanization expand across different operations such as soil preparation, planting, inter cultivation/ weed management and harvesting. However, we require innovative ideas to meet the projected demand of hybrid maize in the state. Promotion of maize based skill development centers and maize based farm machinery banks for small and marginal farmers can be the big game changers for enhancing productivity of hybrid maize in the state as well as country. The private hybrids grow more than public released single cross hybrids under around 58.0% area and need to encourage maize growers to prefer public hybrids for cultivation in the state. To achieve it, there is urgent need to enhance seed production and its marketing of public bred hybrids through public private partnership (PPP). The Farmer's Co-operative Society and contractual farming may play key role in the hybrid seed production with congenial and viable seed storage infrastructure at M.P. State Seed Corporations as Seed Village Concept under the farmer's benefiting government policy. In view of different maturity groups of hybrids, the appropriate contingency plan is required to ensure optimum yield of maize for different domains of the state.

Poster Presentations

Theme- I

Maize Biodiversity and Crop Improvement: Way Forward

I-1 RESPONSE OF SWEET CORN HYBRID TO ESTABLISHMENT METHODS UNDER TEMPERATE CONDITIONS

Fayaz S.[1], Hussain A.[1], Teeli N.A.[2], Ganai M.A.[2], Kanth R.H.[1], Azad A.[1] and Iqbal S.[1]
[1]Faculty of Agriculture, Division of Agronomy, SKUAST-K, Wadura, Sopore
[2] Mountain Research Centre for Field Crops, Khudwani
Shayista027@gmail.com

A field experiment was conducted at Faculty of Agriculture, Wadura (SKUAST-K) to investigate the effect of establishment methods on the yield and quality of sweet corn. The treatments comprised three establishment methods (Transplanting polypot (TP), Transplanting nursery (TN) and Direct Seeding (DS) laid out in RCBD with three replications. Sweet corn variety Sugar-75 of Syngenta was used as the test variety. The Sweet corn's antioxidant activity is significantly increased when cooked, helping to battle cancer, heart disease and protect against cataracts. It is one of the most popular vegetable in the western and advanced countries of the world (ICAR, 2006). Direct seeding often becomes a difficult as seed suffers from bird damage and poor germination resulting in loss of costly seed. Raising the seedlings in polypots root^{-1} trainers under protected conditions is one of the alternatives that need to be explored.The seedlings were transplanted at an age of 18 days. The soil of the experimental field was silty clay loam in texture, neutral in reaction with low N (210 kg ha^{-1}) and P(23.2 kg ha^{-1}) and medium in K (165.5 kg ha^{-1}).The seedling parameters were significantly superior in transplanting polyplot sown in green house. All the growth parameters (*viz.* plant height, dry matter production, leaf area index), days to tasseling, days to silking and yield parameters *viz.* number of cobs plant^{-1}, number of grains cob^{-1}, green cob yield and stover yield and harvest index) were observed to be significantly higher in transplanting polyplot. Overall the study has indicated transplanting polypotaproved superior for realizing higher yield and profitability of sweet corn under temperate conditions.

I-2 META-ANALYSIS OF QTLS ASSOCIATED WITH POPPING TRAITS IN MAIZE

Kaur S.[1], Rakshit S.[2], Choudhary M.[2] and Das A.[2]
[1]Punjab Agricultural University, Ludhiana
[2]ICAR- Indian Institute of Maize Research, Ludhiana

The rising demand for popcorn invited scientists to seek ways to increase its popping quality with higher yield of popcorn cultivars. Towards this direction identification of accurate and consistent QTLs across different genetic backgrounds and environments is necessary for effective use in marker-assisted selection. Several studies have identified QTLs for popping traits in maize. However, their consistency is yet to be tested. In this study, attempts were made to locate the consistent QTLs related to popping traits by combining QTL mapping results from number of reports by using metaQTL approach. Ninety-nine QTLs related to popping traits reported in ten studies were assembled and projected on a reference map "Genetic 2005" with about 2000 markers using BioMercator v4.2. Meta-analysis was performed employing the models with least AIC value. A total of ten metaQTLs were identified which were allocated to two chromosomes, *viz.*, chromosome 1 and 6. Seven metaQTLs were located on chromosome 1 and three on chromosome 6. Three out of ten identified metaQTLs (mQTL1_6, mQTL6_2 and mQTL6_3) revealed small genetic lengths of 1.97–3.09 cM and physical length of 0.43–2.5 Mb. Due to unavailability of closer flanking markers the physical distance could not be narrowed down. Using gene annotation information available in the maizeGDB, genes present in the ten metaQTL regions were analyzed. A total of 229 genes were shortlisted on the basis of their expression in endosperm and pericarp tissues. The shortlisted genes can be further validated by studying loss or gain of function. Furthermore, some of the identified metaQTL regions coincide with the QTLs related to various agronomic traits like stalk diameter, tassel length, leaf area, plant height from earlier reports. This give an idea of improving the popping qualities and agronomic traits simultaneously. The metaQTL regions can serve as important regions for fine mapping and candidate gene finding. The QTLs reported in these regions can be used in the Marker assisted selection for introgression of popping traits in towards enhancing the popping ability.

I-3 SPRING MAIZE: AN ALTERNATIVE OF SUMMER RICE

Singh R.P., Singh N.K., Bhatnagar A. and Singh V.
G. B. Pant University of Agriculture and Technology, Pantnagar
rajesh_p_singh@ rediffmail.com

Udham Singh Nagar district is known as "Rice Bowl" of Uttarakhand. Rice, wheat, sugarcane and vegetable pea are the most important crops in terms of area, production and economic return. Rice (k*harif*) - Vegetable pea – Rice (summer) is most profitable cropping sequence of *tarai* area. The rice is mainly grown in this area during these two seasons. The high water table makes the area fit for the summer rice cultivation. The productivity of summer rice remains higher than the *kharif* rice due to the low pest infestation during the summer season. During last decade area under summer has increased more than 200 per cent. Due to increase in area of summer rice attack of the insects like brown plant hopper and stem borer has become regular and serious problem in *kharif* rice. Besides this summer rice is also responsible for depletion of ground water table. In spite of knowing these problems farmers don't agree to leave the summer rice cultivation due to high return. Summer rice replacement is possible only when a viable alternative is made available. In this context spring maize has showed a ray of hope. To address this issue consortium approach was adopted involving all stake holders- state agriculture department, scientists from GBPAUT, I/C KVKand industries. Front line demonstration on hybrid maize was initiated by KVK in the year 2018 with financial support of ATMA Udham Singh Nagar over 20 ha area on farmers field. Field days were organized at several places and industry ensured the purchase of produce. After seeing the result farmers expressed their willingness to grow the spring maize in place of summer rice. After noting the potential of spring maize systematic plan was developed by AICRP Maize with objective of testing the various hybrids, developing the package of practice and popularization of spring maize among the farmers at large scale. In the year 2019 varietal and agronomical trials were started and Front line demonstration was conducted at large scale by AICRP Maize, KVK and Agriculture Department. Availability of suitable hybrids was ensured by seed companies and state agriculture department provided the subsidy on seed. Hybrids from Pvt. companies and GBPUAT Pantnagar were tested together at KVK farm and fields of few farmers. Joint visit of all stakeholders was conducted at varietal demonstration sites. Pantnagar hybrids in pipeline namely Pant Sankar Makka 5 (DH 291) and Pant Sankar Makka 6 (DH 296) showed potential for spring cultivation and appreciated by all. In terms of yield both the hybrids were near to popular Pvt. sector hybrid DEKALB 9108 but maturity of Pant Sankar Makka 6 was late by 3-5 days. By adopting spring maize over summer rice on an average farmer earned the net profit of Rs. 25539 per hectare along with saving of 14-18 irrigations. Due to collective efforts of all stakeholder spring maize has covered about 1000 ha area in Udham Singh Nagar district. Within 1-2 years we will come out with suitable hybrids and complete package of practices for spring maize.

I-4 HETEROTIC GROUPING OF TROPICAL MAIZE (*ZEA MAYS*L.) INBRED LINES

Patil N.L.[1], Kachapur R.M.[2], Wali M.C.[1] and Harlapur S.I.[2]
[1]Department of Genetics and Plant Breeding, University of Agricultural Sciences, Dharwad
[2]AICRP on Maize, University of Agricultural Sciences, Dharwad
tryanother609@gmail.com

Heterotic grouping of inbred lines helps in increasing the efficiency of heterosis breeding by increasing the genetic diversity among the germplasm and increasing the probability of obtaining heterotic single cross hybrids by making inter heterotic group crosses. Twenty CIMMYT inbred lines (seventeen yellow lines and three white lines) were crossed to three testers in line x tester design and evaluated for grain yield and other quantitative characters during Kharif, 2018. Two testers CM-111 and GPM-581 were used for heterotic grouping as they showed contrasting gca effects for grain yield and related traits. Heterotic grouping was based on sca effect and grain yield of lines along with these two testers. Out of the twenty lines, 6 lines were grouped under HG-A and 7 to HG-B three lines showed positive sca effects with both the testers thus they were grouped under HG-AB. The mean grain yield of test cross hybrid was 52.30 q.ha^{-1} and cross VL-108723 (HG-AB) x CM-111 recorded highest grain yield of 75.08 q.ha^{-1} which was 19.03% superior over best performing check 900 M Gold. Out of six lines in HG-A four lines showed low gca namely VL-102 with gca effect of -17.64 q.ha^{-1} whereas of the seven lines six lines in HG-B group showed high gca namely VL-1018527and VL-058725 with gca effects of 11.15q.ha^{-1} and 8.79 q.ha^{-1} respectively.It indicates tester CM-111 produced heterotic hybrids even with low gca lines thus demonstrating presence of complementary alleles to that of lines. On the other hand, tester GPM-581 produced heterotic hybrids when paired with high gca lines. The white lines VL-058725, VL-1018527 and VL-0536 used in the present study where of African origin, when used as female parent and crossed with tester GPM-549 resulted in heterotic hybrids with grain yield of 64.94 q.ha^{-1}, 68.4 q.ha^{-1} and 63.99 q.ha^{-1} respectively and showed resistance to turcicum leaf blight. On forming heterotic groups, these lines were placed in different groups indicating that grouping of lines was not based on the origin of the lines but on the heterotic reaction between lines and testers. But three lines SNL-1563, SNL-1574 and SNL-1559 derived from synthetic population DMSyn-C0 were together grouped in HG-B indicating these lines showed similar heterotic pattern.In the future line of work, the inbred lines belonging to each of heterotic groups can be recombined among themselves to build new populations which are diverse from each other. Thus, the inbred lines derived from each of the heterotic group are expected to be heterotic against each other.

I-5 TALEN-MEDIATED GENOME EDITING IN MAIZE IMPROVEMENT

Jaishreeprianka R. and Mandal S.S.
Department of Plant Breeding and Genetics, Bihar Agricultural University, Sabour, Bhagalpur

Breeding for improved crop is the ultimate aim of plant breeders and geneticists. Ever since the beginning of civilizations, maize domesticated and continuously bred for increased productivity. Continuous processes of selection and inbreeding has resulted in the uniformity among the genotypes and has led to narrowing of the genetic diversity in maize. However, through conventional breeding, the variation that is already present in the germplasms alone can be exploited. Breeding improved crops is vital for satisfying the constant demands of the ever-growing global population. Mutation breeding could prove useful in creation of variation that is not present in the germplasms. But creation of site specific mutation has been the major goal of the scientists for many years. With site-specific gene editing tailored genotypes with mutations, disrupted gene function (gene knockout), genetic correction or enhancement through gene replacement, genetic regulations can be produced. The genome engineering tools include Meganucleases, Zinc Finger Nucleases (ZFN), Transcription Activator Like Effector Nucleases (TALEN) and Clustered Regularly Interspaced Short Tandem Repeats (CRISPR) / Cas system. They induce targeted double strand breaks and utilize the host repair mechanism to repair the damage. Each of these systems has their own advantages and disadvantages. TALEN is a bacterial TAL-Effector protein derived endonuclease which can induce targeted double strand breaks in the genome. TALENs are engineered by fusing TALE proteins with an endonuclease FokI. They are highly specific in cleavage and reduced off target effects due to the unique structure of their TALE repeat domains. Alongside ZFN and CRISPR / Cas, TALEN is widely used in genome editing applications. With certain improvements and proper utilization genome engineering can be used to develop improved maize to feed the ever growing population of the world.

I-6 KNMH-4010141: A HIGH YIELDING, EARLY MATURITY SINGLE CROSS MAIZE HYBRID SUITABLE TO PENINSULAR ZONE OF INDIA

Sravani D., Sumalini K., Usha R.G., Manjulatha G., Rajanikanth E., Nagesh K.M.V., Sobha R.T., Pradeep T., Bhadrunaik D., Anuradha G., Vijaybhaskar A. and Uma R.R.
Agricultural Research Station, Karimnagar
Professor Jayashankar Telangana State Agricultural University, Hyderabad

Kharif maize mainly grown under rainfed conditions. Early maturing hybrids minimise the risk of cultivar to be vulnerable to drought conditions. The new hybrid KNMH 4010141 gives an opportunity to widen the choice of cultivars with good adaptation and performance. KNMH-4010141 is a high yielding early maturity single cross maize hybrid and showed stable resistance to TLB, MLB, RDM, ESR and C.Rust diseases and moderately tolerant to stem borer under artificial conditions. The hybrid KNMH-4010141 developed from ARS, Karimnagar. It was tested in All India Coordinated Maize Improvement Project trails during *Kharif* , 2010, 2011 and 2013 at twenty locations in Peninsular zone (Six locations in 2010, seven locations in 2011 and seven locations in 2013) along with checks Prakash, JH3459 and PMH5. High yield potential of the hybrid KNMH-4010141 was observed during three years of evaluation. This hybrid ranked second per grain yield in zone IV among all test entries including checks during 2011(7240 kg ha^{-1}) and 2013 (9311 kg ha^{-1}).On an average the hybrid KNMH-4010141 recorded grain yield of 7954 kg ha^{-1} with 23-49% high grain yield over the checks Prakash (6453 kg ha^{-1}), JH-3459(6427 kg ha^{-1}) and PMH-5 (6268 kg ha^{-1}). Looking to its high yield potential, tolerance to majority of the diseases and moderately tolerant to stem borer the hybrid KNMH-4010141 is identified for notification for *Kharif* season in peninsular zone and it was released in the year 2017 for general cultivation for *kharif* season of peninsular zone .

I-7 GGE BIPLOT BASED STABILITY ANALYSIS OF EXPERIMENTAL HYBRIDS FOR BABY CORN

Kumar P.[1], Kumar S.[1], Choudhary M.[1], Chikkappa G. Karjagi[1], Kumar B.[1], Jat B.S., Singh N.K.[2], Sinha S.K. [3] and Rakshit S.[1]

[1]ICAR-Indian Institute of Maize Research, Ludhiana
[2]G.B. Pant University of Agriculture and Technology, Pantnagar
[3]Indira Gandhi Krishi Vishwavidyalaya, Raj Mohini Devi College of Agriculture & Research Station, Ambikapur
pardeep.kumar656@gmail.com

Baby corn cultivation in peri-urban areas offers an excellent opportunity to augment the farmer's income. Baby corn has the immense potential to fetch foreign currency because of its huge demand in international market owing to its good taste, nutritive values, being free from pesticide residues and its utilization in preparation of food products. In addition the husk obtained from baby corn cultivation serves as excellent source of green fodder for livestock production. The multi-location testing puts emphasizes mainly on identification of new superior cultivars over commercial cultivars, while giving very less importance to genotype × environment interaction (GEI). In the present study, performance of 37 baby corn cross combinations (including three checks) was evaluated for green ear yield, baby corn yield and husk yield over three locations (environments) in *kharif* season of 2018. Environment attributed higher proportion of the total variation (96.70-98.67.0%), followed by genotype (0.83-1.88%) and GEI (0.48-1.41%). Superior stable hybrids for green ear yield, baby corn yield and husk yield could be identified using GGE biplot graphical approach effectively. 'Which won where' plot for each of the traits partitioned testing locations into two mega-environments with different winning genotypes for different traits in respective mega-environments. This clearly indicates that though the testing is being conducted in many locations, similar conclusions can be drawn from one or two representatives of each mega-environment. Thus, the stability analysis can help to classify the stable as well as location specific baby corn hybrids.

I-8 GENERATION OF MUTANTS FOR *ZMPLA1* GENE THROUGH CRISPR/CAS9 RIBONUCLEOPROTEIN COMPLEX IN MAIZE

Sudha M.K., Rangari S.K., Kaur H., Uppal N., Manchanda P., Sharma P. and Vikal Y.

School of Agricultural Biotechnology, Punjab Agricultural University, Ludhiana

Doubled haploid generation from the haploid plants accelerate production of homozygous lines in single generation. In maize, haploids are produced using crosses to Stock 6, a haploid inducer reported in 1959 but frequency is very low. Recently three independent studies reported knockout of *ZmPLA1* gene which is responsible for haploid induction mechanism in Stock 6. On the other hand, CRISPR/Cas9 ribonucleoprotein (RNP) complex made possible to precisely knockout any gene of interest without altering the whole genome with added advantage of totally transgene free system. In the present study the sequence of gene *ZmPLA1* was fetched from MaizeGDB. The overlapping primers were designed to cover the whole gene. The amplicons were cloned and sequenced. The gRNAs were designed based on the consensus sequence showing 100% homology with reference gene, using software CRISPR-P-V2 and CHOPCHOP. The in vitro transcribed sgRNA were mixed with Cas9 buffer and delivered into immature embryos via particle gun. A total of 450 plants have been regenerated and are being analysed through T7E1 assay and will be further confirmed through sequencing.

I-9 IDENTIFICATION OF STABLE GENOTYPES ACROSS THE ECOLOGIES USING AMMI ANALYSIS

Kaur Y.[1], Kumar R.[1], A.[1], Das A.K.[1], Singh S.B.[2], Shahi J.P.[3], Patel M.B.[4] and Rakshit S.[1]

[1]ICAR-Indian Institute of Maize Research, Ludhiana

[2]Regional Maize Research and Seed Production Centre, ICAR- Indian Institute of Maize Research, Begusarai

[3]Institute of agricultural sciences, Banaras Hindu University, Varanasi

[4]Anand Agricultural University, Regional Station, Godhra

Maize is an important cereal crop after wheat and rice. It is grown on a wide range of environments across the world. Genotype × environment interaction affects the relationship between phenotype and genotype of in breeding programmes, particularly for quantitative traits. So multi environment trials (MET) are used for evaluation and identification of stable genotypes across the environments. So, to assess the differential performance of the 18 genotypes, an experiment was conducted under three different locations and different environments *viz*., Ludhiana, Godhra and Varanasi under irrigated, rainfed and drought condition, respectively during *kharif* 2017. Randomized completely block design (RCBD) along with two replications was used. Data was recorded for grain yield and then subjected to additive main effects and multiplicative interaction (AMMI) analysis to understand the interactions between genotypes and environment and identify the stable genotypes. In AMMI1 biplot the PC1 explained 65.07 percent of the variation. Genotypes ZH 161434 and ZH 161311 with high mean yield and wider adaptability were found stable across the environments. Genotypes ZH 161038 and ZH 161083 were best performing genotypes under irrigated environment at Ludhiana, whereas under rainfed conditions at Godhra, ZH 161434 and ZH 161093 revealed good grain yield. Genotype ZH 161063 was specifically adapted under drought conditions at Varanasi. The best selected genotypes having wider adaptability across the environments can be used further in the breeding programmes.

I-10 HETEROTIC GROUPING AND MOLECULAR CHARACTERIZATION OF MAIZE INBRED LINES USING SNP MARKERS

Madankar K.S., Shahi J.P., Singamsetti A. and Kumari S.
Department of Genetics and Plant Breeding, Banaras Hindu University, Varanasi

Maize (*Zea mays* L.) is one of the important cereal crop after wheat and rice. As a maize is a cross pollinated crop, development of hybrids by exploiting heterosis can boost up its yield potential. Many researchers developed hybrids and they are continuously performing well, but to satisfy the demand of an increasing population, there is a need to be speed up the hybrid development program and develop high yielding hybrids that break up the yield plateau. Hybrid development programs in maize predominantly depend on the genetic diversity in inbred lines as more divergence among the parent results in maximum heterosis. The amount of genetic divergence can play a crucial role in heterotic grouping of all the germplasm available. A heterotic grouping is a collection of all inbred lines that tend to produce vigorous hybrids when cross with inbreds of different groups, but not when cross with lines of the same group. Grouping of inbred lines prevents the establishment of low performing hybrids that save time as well as money. Heterotic grouping can be done at phenotypic levels (GCA, SCA and heterotic study) as well as genotypic levels (grouping based on molecular markers). Genotypical level grouping avoid environmental effects, thus it gives more reliable results. There are different types of molecular markers each of has its own advantages and disadvantages. Among that, SNP marker best for heterotic grouping as it identifies a single base change, distributed all over the genome and uses the advantages of genome sequencing. Thus heterotic grouping through SNP genotyping helps to identify the diverse inbred lines. Combining current heterotic information based on combining ability tests and the genetic relationships inferred from molecular marker analyses may be the best strategy to define heterotic groups for the future maize improvement program. The grouping of inbreds lines by SNP markers could be valuable in planning and reducing the number of planned crosses in a breeding program before using the more expensive field performance based methods.

I-11 EVALUATION OF MAIZE INBRED LINES FOR YIELD AND YIELD ATTRIBUTES UNDER RAINFED CONDITIONS

Usharani G., Sravani D., Rajanikanth E., Manjulatha G., Vijayabhaskar A. and Uma R.R.
Agricultural Research Station, Karimnagar
Professor Jayashankar Telangana State Agricultural University, Hyderabad

Drought is one of the major abiotic stress factor severely affecting the grain yield and often causes extreme economic crop losses. Maize (*Zea mays* L.) is an enviable prime crop in global agriculture and ranks third next to wheat and rice in terms of production. Maize is particularly sensitive to water stress during the period of one week before flowering and two weeks after flowering causing severe losses when exposed to drought conditions during flowering due to increased anthesis silking interval. As such, improving drought tolerance in maize has become one of the top priorities in maize breeding programs. Prolonged drought spells at flowering during *kharif* in maize crop is a recurring phenomenon in the state of Telangana. It is an essential pre-requisite to identify maize germplasm with superior drought tolerance. Pertaining to this context, the present study was conceptualized to identify potential drought tolerant inbreds under rainfed conditions involving seventy genotypes against the check KDTML-3 (Drought tolerant line registered with NBPGR) at Agricultural Research Station, Karimnagar during *kharif* 2018. The inbreds WNC-52-1, IB-8, 52186, IB-117 and IB-4 were found to be superior with a grain yield range of 85 to 110 g per plant under rainfed conditions. These lines are suitable for rainfed conditions as they have exhibited >15% superiority over the check KDTML-3. Drought tolerant inbred lines identified in this study could be utilized for future breeding programme for the development of climate resilient maize hybrids. These lines can be utilized as a future perspective in the development of maize hybrids to tolerate the extremes of climate change which is posing a serious effect on the growth and development of the crop.

I-12 ASSESSMENT OF GENETIC DIVERSITY AND ITS RELATIONSHIP WITH HETEROSIS FOR FORAGE TRAITS IN MAIZE (*Zea mays* L.)

Doggalli G., Mahadevu P., Lohithaswa H.C., Shekar B.G. and Mallikarjuna
Zonal Agricultural Research Station, Mandya, University of Agricultural sciences, Bangalore

An investigation was carried out to estimate the genetic diversity, combining ability and to assess the relationship between parental diversity and heterosis in newly developed inbred lines for forage traits in maize (Zea mays L.) at the College of Agriculture, V. C. Farm, Mandya and Main Research Station, Hebbal during 2018-19. Fifty inbred lines were grouped in to seven clusters using Mahalanobis D2 statistic. The cluster II accommodated maximum number of inbred lines (18) followed by cluster III (14). Combining ability analysis was performed using 50 lines ad four testers by employing Line × Tester mating design. The ratio of GCA to SCA variance revealed the preponderance of non-additive gene action in the expression of all the traits under study. The lines viz., 1-50-7, 1-63-5 and 1-17-19 in E1;1-17-19, 5-6-1 and 1-50-7 in E2; 1-50-7, HCL-7 and 2-4-1-2 on pooled basis and tester CAL-1443 were identified as best general combiners for forage yield and yield related characters. Among crosses, 1-5-12 × VL121096, 1-17-19 × CAL-1443, 1-19-5 × CAL-1443, MAI-179 × VL108867, 1-44-9 × CM-202, 1-50-7 × CM-202, 1-63-5 × CAL-1443 and 5-12-1-1 × CAL-1443 exhibited highest significant sca effects and high heterosis over checks for green forage yield. These hybrids have to be further evaluated across locations and over seasons to select best hybrids for commercial exploitation. The parents were grouped into four classes based on mean and standard deviation of D2 values and found that maximum number of heterotic crosses resulted from parents included in medium divergence classes. Genotypes viz., 200 hybrids, 50 inbred lines and 4 testers along with two standard checks (CM-202 and Nithyashree) were evaluated for their performance against TLB. Out of 200 hybrids, 98 hybrids showed resistance, 58 moderately resistance, 32 moderately susceptible and 12 susceptible to TLB. Among 56 parents, 26 lines were showed resistance, 12 lines were expressed moderately resistance, 10 lines were found moderately susceptible and six lines recorded in susceptible reaction. The standard checks, CM-202 and Nithyashree found susceptible and resistant to TLB, respectively.

I-13 ANALYSIS OF REPEAT MARKERS IN HIGHLY POLYMORPHIC GENETIC REGIONS OF MAIZE GENOME

Kaur S.[1], Gaganjeet[1], Naliath R.[2], Verma D.[2] and Singh A.[2]
[1]Punjab Agricultural University, Ludhiana
[2]ICAR – Indian Institute of Maize Research, Ludhiana
alla.singh@icar.gov.in

Maize is one of the most versatile crops, suitable for cultivation in different agro-ecological climatic conditions. Maize evolution can be tracked by analyzing DNA polymorphism in the genome. Amongst the various types of DNA polymorphisms, Simple sequence repeat (SSR) are one of the most commonly studied. SSRs result from a biological phenomenon called Replication slippage and are representative of the evolutionary drive acting on a particular loci. Crops adapt under natural or selective pressures and SSR polymorphism results from spontaneous or induced selection. We have analyzed SSR markers in the highly polymorphic regions of the maize genome. It has been found that the nature and identity of SSR markers in polymorphic regions is different from that observed throughout the genome. The polymorphism and its putative reasons are discussed.

I-14 EFFECT OF THIOUREA SUPPLEMENTATION ON *IN VITRO* SEEDLING GROWTH IN MAIZE LANDRACES

Verma D.[1], Ahmed Z.[2], Jat B.S.[1], Kumar R.[1], Singh A.[1] and Rakshit S.[1]
[1]ICAR-Indian Institute of Maize Research, Ludhiana
[2] Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Srinagar
alla.singh@icar.gov.in

Maize landraces are valuable genetic resources with a historical origin, often genetically diverse, locally adapted and associated with different practices and farmer's traditional knowledge. Landraces are an important component of genetic resource base of a crop. Certain niche areas like tribal belts and some regions in North-East are known to have a preference for landraces owing to their organoleptic properties. In the wake of changing climatic scenarios and new cropping patterns, early plant stand is beneficial as it allows escape through various stressors. Thiourea, a sulphhydryl compound, is known to be a potential bioregulator as it has been shown to enhance the yield and photosynthetic efficiency in stress conditions in many crops. Enhanced seed germination can help in mitigating certain plant stresses that appear early in the season and delay seedling growth. In order to evaluate the effect of thiourea supplementation on in vitro seedling growth in maize landraces, twenty maize landraces were treated with a defined concentration of thiourea and incubated in Plant growth chamber. Parameters monitored included shoot length, root length and number of roots. Thiuorea impacted the landraces' performance differently. Certain landraces responsed positiviely in terms of root and shoot growth upon treatment with thiourea. The study indicates that at appropriate doses, thiourea can be used to enhance performance of maize landraces in niche areas where they are preferred.

I-15 CROP IMPROVEMENT IN MAIZE THROUGH HETEROSIS AND COMBINING ABILITY

Kumar S.

Department of Genetics and Plant Breeding, Swami Keshwanand Rajasthan Agriculture university, Bikaner
skbshn@gmail.com

Maize (*Zea mays* L.; 2n = 20) is the third most important crop after rice and wheat in the world. Maize is known as "queen of cereals" due to its highest genetic yield potential among the cereals. Development of hybrids is important to increase yield *per se* and enhance resistance for important diseases. In any hybrid breeding programme, choosing of the appropriate parents is important to realise significant heterosis for economic traits. The invention of heterosis phenomenon (Shull, 1908), the development of hybrid breeding technology and exploitation of heterosis in maize are the land marks in the biological sciences during the present century. A number of cultivar *e.g*., single crosses, double crosses, varietal hybrids, multiple hybrids, composites, synthetics, pools, populations *etc.,* are available to maize growing farmers for commercial cultivation by virtue of the crop being highly cross pollinated. It is estimated that the use of hybrids and heterosis increases yields nearly 15% per annum in maize (Duvick, 1999). The study of heterosis can provide the basis for the exploitation of valuable hybrid combinations in the breeding programme. Combining ability studies provide information on the relative importance of GCA and SCA variance for interpreting the genetic basis of important traits. This helps us to assess the nature of gene action and in identifying superior parental lines for their *per se* performance. The best combinations with high general combining ability of individual lines are helpful to get more desirable recombinants which enables further improvement of the crop.

I-16 ESTIMATION OF GENETIC COMPONENTS FOR GRAIN YIELD AND QUALITY TRAITS IN MAIZE

Sharma P., Kamboj M.C and Singh N.
Chaudhary Charan Singh Haryana Agricultural University, Regional Research Station, Karnal
sharmapreeti.genetics@gmail.com

Maize has been preferred by the evolutionists, geneticist and plant breeders to develop concepts, quantitative genetic models and improved populations/hybrids for practical use over last many decades. It is an economically and nutritionally important cereal crop being cultivated in different agricultural zones under diverse situations of rainfall and altitude around the world. The dramatic increase in production and yield levels of maize during the last four decades is mostly due to genetic improvement of hybrids and better production technology. It is well known fact that greater is the variability among the parents, the tremendous are the chances of further improvement. Generation mean analysis is a useful technique that provides the estimation of main genetic effects (additive, dominance and their digenic interactions) involved in the expression of quantitative trait such as yield and its components traits. Therefore, current study has been designed to understand the nature and inheritance of grain yield and quality traits of maize and is necessary for proper choice of breeding procedures for developing QPM hybrids with increased grain yield. The present study was carried out with six crosses *viz*. HKI 209 x HKI 1128, HKI 209 x HKI 163, HKI 1332 x HKI 1128, HKI 1332 x HKI 163, HKI 325-17AN x HKI 1128 and HKI 325-17AN x HKI 163 with their six generations *viz.* P_1, P_2, F_1, F_2, BC_1 and BC_2. The results obtained for genetic components (genetic effects) are have been explained for grain yield and quality characters *viz*., protein content, tryptophan content, oil content and starch content (expressed in percentage) according to the analysis procedure for three parameter and six parameter models. Both individual scaling test (A, B, C and D) and joint scaling tests were used in all the six crosses to determine whether at all, the additive-dominance model was adequate for different traits. Further, the three parameters m, (d) and (h) were estimated through joint scaling test to depict whether the additive-dominance model was adequate or not or to detect epistasis. In the presence of epistasis or inadequacy of three parameter model, the additive (d) and the dominance (h) effects and non-allelic interaction components (additive x additive (i), additive x dominance (j) and dominance x dominance (l)) of generation means were estimated according to Hayman (1958). The chi square (χ^2) value was significant according to joint scaling test for all the characters in all the six crosses studied, except for oil content in cross HKI 325-17AN × HKI 1128 which were not significant, showing the adequacy of three parameter model where the additive dominance model was found to be fitted. Also the significant values of scale A, B C, D in all the crosses for all the characters indicated the presence of epistasis (non-allelic interaction), which was also inferred from the generation means. As the three parameter models did not satisfactorily explain the genetic variability for all these traits, therefore, a six parameter model was applied to accommodate epistatic interactions. Results revealed that duplicate type of interaction was apparent for protein, tryptophan, oil and starch content in cross HKI 325-17AN × HKI 163; oil, tryptophan and starch for cross HKI 1332 x HKI 1128; however, complementary type of interaction was reported for protein content in cross HKI 325-17AN x HKI 1128 and oil content in cross HKI 209 x HKI 163. For grain yield, dominance gene action is more pronounced as the magnitude of h (dominance) is higher than d (additive) in 5 crosses viz., HKI 209 x HKI 1128, HKI 209 x HKI 163, HKI 1332 x HKI 1128, HKI 1332 x HKI 163, HKI 325-17AN x HKI 1128. For protein content additive effects were significant for HKI 209 x HKI 1128, HKI 1332 x HKI 1128, HKI 1332 x HKI 163 as well as epistatic interactions played a significant role in inheritance of this trait and it was also revealed that significant magnitude of l and non significant magnitude of h indicated the dispersal of alleles in the parents. The involvement of duplicate type of non-allelic gene interactions was prominent to explain the inheritance of tryptophan content. For oil content additive, dominance and interactions played a significant role in inheritance of this character in these crosses however the magnitude of dominance effect was more pronounced. For starch content the significant magnitudes of both d (additive) and h (dominance) and all non allelic interaction (i, j and l) in HKI 1332 x HKI 163, HKI 325-17AN x HKI 1128 and HKI 325-17AN x HKI 163 revealed that additive, dominance and interactions played a significant role in inheritance of this character in these crosses. It was concluded that both additive[d] and dominance [h] gene effects were significant for most of the traits studied, indicated that both additive and dominance effects were important in the inheritance of these traits. Significant epistatic gene interaction (i, j and 1) were also observed for all the characters under study suggesting the existence of epistasis gene action in the maize crosses.

I-17 STABILITY OF EXPERIMENTAL WINTER MAIZE HYBRIDS TESTED ACROSS THE ENVIRONMENT OF BIHAR USING GGE BIPLOT AND AMMI ANALYSIS

Singh S.B.[1], Kumar S.[1], Yathish K.R.[2], Jat B.S.[3], Chikkappa G. Karjagi[4], Kumar B.[4], Kumar B.[5], Kumar A.[6], Kasana R.K.[1] and Rakshit S.[3]

[1]Regional Maize Research and Seed Production Centre, ICAR-Indian Institute of Maize Reseach, Begusarai

[2]Winter Nursery Centre, ICAR-Indian Institute of Maize Reseach, Hyderabad

[3]ICAR-Indian Institute of Maize Reseach, Ludhiana

[4]Delhi Unit office, ICAR-Indian Institute of Maize Reseach, New Delhi

[5]Bihar Agricultural University, Sabour, Bhagalpur

[6]Tirhut College of Agriculture, Dholi , Muzaffarpur

saan503@gmail.com

Maize (*Zea mays* L) being of a protean nature crop acclimate facilely to a wide range of production environments. Maize is the highest contributor of more than 1046 million tonne (FAOSTAT, 2018) annually to the global food basket among the cereal food crops out of which India shares around 2.2% with production of 26.26 MT from 10.20 million hectare. The projected demand for maize in India is expected to be 45 Mn MT of Maize by the year 2022. To meet this demand, there is need to develop high yielding and highly stable single cross hybrid varieties. The phenotype of the hybrid is the result of Genotype (G) x Environment (E), such G x E interaction effect poses problem to the breeder while selecting a genotype with consistent performance across different environments. Multi-location testing of cultivars plays a key role in any breeding programme. Hence, looking into the above facts, multilocation testing of thirty-two newly crossed hybrids along with four checks DHM-117, BIO-9544, P-3396 & DKC-9081 was made across six environments *i.e.* three locations *viz.* Begusarai, Sabour & Dholi and two seasons (rabi 2017-18 & rabi 2018-19) in the Bihar, India using GGE biplot & AMMI model to analyze and interpret the complex GEI in MLT data. The objectives of the study was to estimate the G×E of hybrids, identify high yielding single cross maize hybrids with high stability and partition of testing location into mega environments. Analysis of variance clearly showed the significant effect of G, E and GE for all the traits studied. It was observed that environment was the most important source of variation for all the traits. For trait grain yield, environment contributed for 77.84% of the variation while 16.31% and 5.72% contribution of the total variation was made by the genotype and GE respectively. Performance and stability of the genotypes were visualized graphically through GGE biplot. The first two PC (Principal component) explained 71.92% variation for grain yield, 86.6%, 64.49% & 98.48% for the traits grain filling duration, ear height & anthesis silking interval respectively. Hybrids IMHSBM-28 & IMHSBM-36 was observed as the high yielding as well as highly stable across the location. Which won where graph showed that IMHSBM-1 was winning genotype in Begusarai environment for both the seasons while genotype IMHSBM-17 & IMHSBM-24 was winning in both Sabour & Dholi environment for the trait grain yield.

I-18 BREEDING FOR HIGH KERNEL ROW NUMBER: A STRATEGY TO INCREASE PRODUCTIVITY OF FIELD CORN (*ZEA MAYS*. L) HYBRIDS

Mukri G., Gadag R.N., Bhat J.S., Sharma G., Pal D and Kumar R.

ICAR-Indian Agricultural Research Institute, New Delhi

ganapati4121@gmail.com

Kernel row number (KRN) is an important component of yield during the domestication and improvement of maize. It is an important agronomic trait of the female inflorescence and a significant breeding target. Grain yield is a complex trait and its heritability is low by virtue of its interaction with environment. Yield components exhibits higher heritability and better stability across environment and improvement in grain yield can be achieved by increasing yield components. Inbred lines improvement for yield component traits plays major role in enhancing the productivity of hybrids. Inbred lines with high yield *perse* were derived from different source populations through pedigree method. Total 80 inbred lines with varying KRN were evaluated across two locations, IARI, New Delhi and IARI-RRC Dharwad during *kharif* 2017 and *rabi* 2018-19 respectively. Among them, 45 inbred lines comprising low (up to 12 KRN), medium (14-18) and high KRN (20 and above KRN) were selected. Based on synchrony in flowering, six inbred lines each from low, medium and high KRN categories were subjected to crossing each other in diallele manner. Hybrids so obtained showed significant variation for KRN and other yield component traits. The KRN in hybrid showed maternal effect. The combinations having, low KRN X low KRN has not expressed any significant heterosis but the cross involving medium KRN X low KRN, medium KRN X medium KRN and high KRN X medium KRN showed significant heterosis for grain yield. Heterosis is manifested by degree of allelic diversity between two parents involved in cross combination, complementation between loci involved in deciding KRN also may independently responsible for increasing hybrid performance.

I-19 IDENTIFICATION OF STABLE TROPICAL MAIZE INBRED LINES FOR ITS KERNEL SIZE AND KERNEL WEIGHT

Kumar C.V.[1], Gadag R.N.[1], Mukri G.[1], Kumari J.[2], Bhat J.[1] and Gupta N.[3]
[1]ICAR-Indian Agricultural research Institute, New Delhi
[2]ICAR-National Bureau of Plant Genetic Resources, New Delhi
[3]ICAR-National Institute for Plant Biotechnology, New Delhi
ganapati4121@gmail.com

Kernel size and kernel weight are the primary yield components contributing significantly through direct effect on final grain yield and indirect through other yield contributing components such as ear length, kernel row number and kernel number per ear. Further compared to grain yield, these component traits have higher heritability and better stability across environments. Having this information in hand, we evaluated 280 germplasm for its kernel size and kernel weight in *rabi* 2017-18. Among them, 42 genotypes were selected based on superior performance for kernel size and weight and further evaluated along with 3 checks in replicated trial over three environments during *kharif* 2018. Test weight is showing positive significant correlation with kernel length, kernel thickness and yield. Kernel length positively associated with kernel thickness. All the three test environments adequately discriminated the genotypes and represented the average of environments for the expression of kernel related characters. The genotype, AI 45 found ideal genotype for kernel length, AI 33 for kernel thickness, AI 12 for test weight and AI 23 for grain yield across the environments. Among the genotypes, AI 04 is found to be stable for kernel size and kernel weight across all the environments and also having lesser AMMI stability value of 0.09 followed by AI 37. These identified maize inbred lines can be utilized for the development of suitable high yielding, stable maize hybrids.

I-20. IDENTIFICATION OF COMPONENT TRAITS CONTRIBUTING TO YIELD IN BABY CORN

Senjam P.[1], Konsam J.[1], Singh S.D.[1] and Nongmaithem N.[1]
[1]AICRP on Maize, Directorate of Research, Central agricultural University, Imphal
puspasenjam@gmail.com

To study the association ship of different yield attributing traits in baby corn, an experiment consisting of fourteen lines of baby corn was conducted during *kharif* 2018. Among the fourteen traits studied, number of baby corn per plant exhibited highest significant positive correlation with both baby corn yield with husk and baby corn yield without husk showing its significant contributions towards yield improvement. Days to 50% tasseling and 50% silking recorded desirable negative significant correlation with yield and number of baby corn per plant. In a similar manner, days to first picking and second picking showed significant negative correlation with yield and number of baby corn per plant. Further days to 50% tasseling and 50% silking exhibited significant positive correlation with days to first and second picking. Overall result of the study revealed that selection for traits like number of baby corn per plant, days to 50% tasseling, days to 50% silking, days to first and second picking would have influential contribution towards yield improvement in baby corn.

I-21 COMBINING ABILITY ANALYSIS FOR YIELD AND YIELD CONTRIBUTING TRAITS IN POPCORN (*ZEA MAYSEVERTA L.*) UNDER TEMPERATE CONDITIONS

Dar Z.A., Lone A.A., Dar S.A., Habib M., Khuroo N.S., Ali G., Abidi I., Naseer S., Rasool F., Ahangar M.A., Bashir S., Nissa S., Rashid Z., Hakeem S.A., Bahar F.A., Alie B.A. and Haq S.A.
AICRP on Maize, Srinagar
Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir

The present investigation was aimed to estimate combining ability effects for yield and yield related traits in popcorn using line × tester analysis. Six inbred lines, three testers and resulting 18 crosses were evaluated at two locations during *Kharif* 2018in a complete randomized block design.. ANOVA for combing ability revealedsignificant mean squares of GCA and SCA for all the traits. The estimates of variance due to dominance component was higher than due to additive component for traits viz., plant height, kernel rows cob^{-1}, grain depth, 100 grain weight, shelling percentage, grain yield plant^{-1} and protein content. The parent KDPI-8 was identified as best combiner for grain yield plant^{-1} and for most of its contributing traits followed by KDPI-4 and KDPI-6. Among the crosses, KDPI-6 × WIN POP, KDPI-8 × VL POPCORN-1 and KDPI-1 × VL POPCORN-1 exhibited highly significant and desirable SCA effects for grain yield plant^{-1}. Therefore, these crosses could be utilized in heterosis breeding to achieve a quantum jump in maize improvement.

I-22 EVALUATION OF SWEET CORN INBREDS FOR DUS CHARACTERIZATION

Gull A., Lone A.A., Dar Z.A., Ashraf W., Buchh J.H., Viqar-un-Nisa and Arsalan-ul-Haq
Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, FoA, Wadura
audilgull26@gmail.com

Sweet corn is the result of a naturally occurring recessive mutation in the genes which control conversion of sugar to starch inside the endosperm of the corn kernel. Unlike field corn varieties, which are harvested when the kernels are dry and mature (dent stage), sweet corn is picked when immature (milk stage) and prepared and eaten as a vegetable, rather than a grain. Since the process of maturation involves converting sugar to starch, sweet corn stores poorly and must be eaten fresh, canned, or frozen, before the kernels become tough and starchy. A major challenge facing those involved in the testing of new plant varieties for Distinctness, Uniformity and Stability (DUS) is the need to compare them against all those of 'common knowledge'. Protection of Plant varieties and Farmers Right Act (2001) insists on Distinctness, Uniformity and Stability (DUS) characterization of new varieties and recommends the registration of varieties for any one specific novel character. An experiment was carried out at Dry Land Agriculture Research Station (DARS), Budgam, SKUAST-Kashmir to evaluate 35 sweet corn (*Zea mays* L. var. *saccharata*) inbreds laid out in Augmented Block Design (ABD) for DUS characterization using descriptor of Directorate of Maize Research, ICAR, New Delhi (2011).The aim of the present study was to formulate an identification key and to develop varietal characterization as per the guidelines of PPV & FRA for sweet corn (*Zea mays* var *saccharata*) inbreds in Kashmir region of Jammu and Kashmir.The results revealed wide variation in various traits among different sweet corn inbreds. The assessment of 35 genotypes for 31 traits revealed that all the traits were informative with respect to trait expression *cum* characterization.The variation for each character was shown by frequency table and bi-plot representation, revealed distinct characteristics of inbreds for desired selection and indicated that, morphological variations exist with inbreds due to variation in genetic makeup and could be better utilized by breeders in the selection of inbreds based on their specific requirement for further breeding programmes.

I-23 ROOT- SHOOT VARIABILITY IN SWEET CORN INBREDS UNDER WATER STRESS CONDITIONS

Gull A., Lone A.A., Wani M.A., Dar Z.A., Ayoub L., Fayaz F. and Akhter F.
Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, FoA, Wadura
audilgull26@gmail.com

Maize is a crop growing in a wide range of target environments from temperate to tropical climates, but in any given year, approximately 20-25% of global maize area is affected by drought.Root architecture is an important component of plant growth and drought tolerance in maize and has a central role in crop plants response to abiotic stresses. An experiment was carried out at Faculty of Agriculture, SKUAST-Kashmir, Wadura, sopore to evaluate sweet corn inbreds under drought and irrigated conditions. The existing root architecture of maize genotypes needs to be investigated before those traits that influence tolerance can be studied.In view of the loaming threats of the climatic changes there is an urgent need to develop varieties which are able to resist the negative effects of water stress especially in crops like maize which are invariably grown under rainfed conditions in Kashmir valley. This requires study of natural variation in drought related traits to identify the parental lines for encouraging crop breeding programme aimed at developing drought tolerant varieties for sustainable crop yield.The results obtained revealed that mean root depth recorded under drought and irrigated conditions were 109.8cm and 102.9cm respectively. BIOL-23 (155 cm) recorded highest root depth under drought conditions while as BIOL-23 (130) recorded highest root depth under irrigated conditions.The root volume was having mean value of 11.42 cm^3 and 21.19cm^3 under drought and irrigated conditions respectively with highest value recorded in BIOL-21 (37.5cm^3) under drought conditions and BIOL-23 (40.15cm^3) under irrigated conditions. The root traits showed significant results for genotypes as well as for water regimes.The number of leaves statistically showed the non-significant results under both drought and irrigated conditions. The shoot height recorded mean value of 90.58cm and 136.67cm for drought and irrigated conditions respectively with BIOL-62 (114.5cm) and BIOL-8 (181cm) having highest shoot height under drought and irrigated conditions. The shoot traits were significant for shoot height only for genotypes whereas number of leaves and shoot weight were significant both under drought and irrigated conditions. The genotypes *viz.*BIOL-23, BIOL-21, BIOL-62, BIOL-27 and BIOL-50 were found to be promising for drought resilient conditions and can be selected for further breeding programmes.

I-24 SCENARIO OF MAIZE CROP IN MAHARASHTRA

Dhonde S.R.[1], Shinde V.S.[1], Chaudhari C.S.[2] and Kute N.S.[2]
[1] AICRP on Maize, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar
[2]Pulses Improvement Project, Mahatma Phule Krishi Vidyapeeth, Rahuri
somnathdhonde.mpkv@gmail.com

Maize is the third most important cereal after rice and wheat in India. The multipurpose use of maize includes feed, fodder as well as speciality corn like baby corn, sweet corn and popcorn along with industrial raw material. It is a hardy crop well adapted to different environmental condition especially in situation of climate change. Adaptability of maize crop to diverse environment and availability of high yielding hybrid seeds leads to increase area under maize cultivation in India as well as in Maharashtra. In India area, production and productivity of maize was 89.20 lakh ha, production 266.30 lakh tonnes and 2.99 tonnes/ha, respectively during the year 2017-18. Maharashtra is the fourth producer of maize in India producing around 9% (31.25 lakh tonnes) of India's total Maize production. In Maharashtra, during the last ten years i.e. 2006-07 to 2016-17, the area under maize has increased from 5.81 lakh ha. to 10.03 lakh ha., whereas production increased from 11.50 lakh tonnes to 32.21 lakh tonnes. Similarly, the productivity has increased from 1.9tonnes /ha to 3.2 tonnes/ha. The average per year increase in cultivated area of maize is near about 10 per cent and that of production and productivity to the tune of 12 per cent each, in last 10 years. In Maharashtra, Maize is mainly grown in *Kharif* season (9.13 lakh ha), *Rabi* season (2.07 lakh ha) & summer season (0.35 lakh ha). The major maize growing districts in Maharashtra are Nasik (2.3 lakh ha) Aurangabad (1.87lakh ha), Jalgaon (1.5 lakh ha), Dhule (0.69 lakh ha), Sangli (0.54 lakh ha) Jalna (0.66 lakh ha) and Ahmednagar (0.60 lakh ha). In the state, crop is mostly utilized as source of human feed (24%), animal feed (11%), poultry feed (52%), starch (11%), brewery (1%) and seed (1%). Maize has a significant potential for doubling farmer's income as it generates better income and provides gainful employment.

I-25 FINE MAPPING OF DROUGHT TOLERANCE QTL *QKNPE9.1* AND ITS UTILIZATION FOR WATER USE EFFICIENCY IN SPRING MAIZE

Kaur R.[1], Kaur K.[2], Sharma P.[1], Singh A.[1], Gill G.K.[2] and Vikal Y.[1]
[1]School of Agricultural Biotechnology, [2]Department of Plant Breeding and Genetics, Punjab Agricultural University, Ludhiana
yvikal-soab@pau.edu

Drought is considered as one of the major limiting factors in sustainable maize production all over the world as it causes yield reduction by an average of 15% to 20%. Maize is generally grown in *Kharif* season but spring maize is now coming up in India. However, the water requirement is very high but farmers are reluctant to see the long term effect of maize cultivation during spring season. To meet the growing demand of water during spring season, enhancement of maize yield can be achieved by developing water efficient maize hybrids. The objective of the study was to identify and to transfer QTL associated with drought tolerance into spring maize inbreds through marker assisted backcross breeding (MABB). A total of 135 F_8 recombinant inbred lines (RILs) from the cross between CM123 as the susceptible (female) parent and CM140 as the tolerant (male) parent along with parents were evaluated under control and drought stress conditions for two consecutive seasons. The QTLs on chromosome 1, 3, 4, 6, 7 and 9 were identified for drought tolerance under both stress and control conditions. The present study focused on fine mapping of QTL for kernel number per ear (*qKNPE*) present on chromosome 9 (*bnlg1401-umc1634*) explaining phenotypic variance of 23.14% under stressed environment. This region was narrow down by designing 50 new SSR markers between the bracketed QTL (*qKNPE*). Seventeen SSR markers showed the polymorphism between CM123 and CM140. These markers along-with previous mapped markers were employed on RIL population. The QTL analysis narrowed down the genetic distance to 3.8 cM from 11.5 cM and physical distance to 691 kb from earlier distance of 15 Mb flanked by two new SSR markers *viz. PAU_1143* and *PAU_1137*. The *qKPE* is also introgressed through MABB into two spring maize inbreds LM23 and LM24 of hybrid PMH10 for water use efficiency. The foreground selection has been carried out in two generations i.e., BC_1F_1 and BC_2F_1. Also, background selection has been done in BC_1F_1 to check the background recovery of the respective recurrent parents. The plants carrying the QTL with highest recurrent parent background recovery were selected and again backcrossed to respective parent for generation of BC_3F_1 population. The BC_3F_1 plants have been raised during *Kharif* 2019 and the positive plants from each cross (involving LM23 and LM24) were selected. The selected plants were crossed to generated reconstituted versions of PMH10 hybrid. The development of drought tolerant PMH10 hybrid will lead to overcome frequent irrigations during spring season and helps to conserve ground water depletion.

I-26 ELUCIDATING THE GENETIC DIVERSITY OF MAIZE (*ZEA MAYS* L) LANDRACES IN JAMMU AND KASHMIR USING PHENOTYPIC AND MOLECULAR APPROACHES

Yousuf N.[1], Dar S.A.[1], Lone A.A.[1], Dar Z.A.[1], Shikari A.B.[1], Sofi P.A.[1], Jacob S.[2], Neelam S.[3], Nagratana T.K.[4] and Gulzar S.[1]
[1]Department of Genetics and Plant Breeding -Sher-e-Kashmir University of Agricultural Sciences and Technology ofKashmir, Srinagar
[2]ICAR-National Bureau of Plant Genetic Resources, New Delhi
[3]Winter nursery Centre, ICAR-Indian Institute of Maize Research, Hyderabad
[4]Protection of Plant Variety and Farmers Right Act, New Delhi
nidayousufmir@gmail.com

Maize (*Zea mays* L.), also known as corn, is the third most important cereal after wheat and rice that is grown and consumed in the form of food, animal feed and used as raw material in several industrial processes. Since the maize germplasm of the valley has not been fully exploited, documented and utilized systematically, so the screening of the available maize germplasm of diverse origin and its genetic variability analysis will generate information on useful traits. Keeping the above points in view, genetic diversity among 70 maize landraces was examined using morphological and molecular markers with the objective to identify a set of core collection which can be used as source populations for deriving inbred lines for utilization in hybrid breeding programme. The present investigation was conducted separately at Dryland (*Karewa*) Agriculture Research Station during *kharif* 2016-17 and 2017-18, Faculty of Agriculture, SKUAST-K at Wadura during kharif 2017-18 and Mountain Crop Research Station, Larnoo during kharif, 2017-18 with the objective to carry out comparative characterization of maize landraces collected from diverse ecogeographic niches using molecular and morphological markers. The ANOVA revealed significant differences for treatments for all the traits studied except prolificacy and ASI indicating that the material was diverse. Genetic diversity was studied through Mahalanobis D^2statistics and molecular markers. The phenotypic analysis was done as per the standard statistical procedures and molecular analysis was done using NTSYS-pc (version 2.02) software. Phenotypic performance-based clustering using Mahalanobis distance resolved 70 maize landraces in to four major clusters. Maximum inter-cluster distance was observed between clusters III and IV suggesting that genotypes belonging to these two clusters may be used as suitable parents in the future hybridization programme. The molecular diversity analysis using 24 SSR markers clustered all the 70 landraces into nine clusters and significant level of dissimilarity (0.27 to 0.62) was depicted among the landraces. The PIC values ranged from 0.29 (phi 129) to 0.76 (umc 1918). Further, molecular analysis of variance showed that the total genetic diversity is mainly due to within population diversity (93%). The Baysian analysis grouped the 70 maize landraces into two distinct groups regardless of their geographical origin. Both the groups obtained can be used for the formation and improvement of heterotic pools. The crossing between two individuals of different pools might help to exploit the phenomenon of heterosis. These findings will form a major criterion for selection of genetic materials with greater diversity for maize breeding programmes particularly to broaden genetic base of maize population.

I-27 GENETIC MAPPING FOR RED FLOUR BEETLE RESISTANCE IN MAIZE BACKCROSS INBRED LINE POPULATION

Joshi A., Adhikari S., Sahoo S. and Singh N.K.
Department of Genetics and Plant Breeding

G. B. Pant University of Agriculture and Technology, Pantnagar

Red flour beetle *Tribolium castaneum* (Herbst) is a major secondary pest of maize products and is also known to damage the germ portion of whole maize kernels causing yield loss, quality deterioration and at the same time reducing the germination ability of kernels. Though insecticides have been used for its control, the development of new insect tolerant genotypes still remains the most feasible, attractive, cost effective and long term alternative for pest management. As resistance sources are scarce in elite maize lines, teosinte (*Zea mays ssp parviglumis*) following insect bioassay was found to be resistant and therefore used as parent in a cross with flour beetle susceptible but superior maize inbred line DI-103 for construction of backcross inbred line mapping population. Data on four resistance parameters namely, weight loss, number of insect progeny emerged, kernel damage and flour produced were collected on 141 backcross inbred lines in order to identify teosinte introgressed maize lines resistant to flour beetle infestation, to assess the degree and direction of association between different characters imparting flour beetle resistance and also to find markers linked to various quantitative trait loci (QTLs) responsible for different resistant traits. Highly significant differences were found amongst genotypes for all the parameters indicating substantial variability in the population for the traits probably contributed by teosinte. On the basis of cumulative susceptibility index, 83 lines were scored to be resistant and can be utilized as donor for flour beetle resistance in maize improvement programmes. Highly significant positive correlations were found between all trait combinations except for correlation between weight loss and kernel damage which was positive but non-significant (0.165). A total of 18 marker linked genomic regions located on all chromosomes of maize, except chromosome 5 and 6, were found to be significantly associated with red flour beetle resistance. Two major QTLs were detected on chromosome 1 and 3 for kernel damage and they explained 11.17% and 14.88% of the total phenotypic variation, respectively. Highest number of overlapping QTLs i.e., 3 were detected for kernel damage and flour produced. These linked markers after further validation can be used in future for indirect selection for resistance to red flour beetle in maize and the marker associated with clustered QTLs can be used for effective pyramiding of different resistant alleles to breed for durable insect resistance in maize.

I-28 GENETIC STUDIES ON COMBINING ABILITY AND HETEROTIC GROUPING OF MAIZE (*ZEA MAYS* L.)

<u>Dodahatti S.[1]</u>, Kachapur R.M.[1] and Talekar S.C.[2]

[1]AICRP on Maize, University of Agricultural Sciences, Dharwad

[2]Agriculture Research Station, University of Agricultural Sciences, Mugad

sureshdodahatti555@gmail.com

Maize (*Zea mays* L.) is one of the major cereal crop of the world and India. It ranks third next to wheat and paddy in production. The productivity of maize in India is low when compared to world productivity. One of the possible ways in enhancing the productivity is through exploitation of heterosis. In the present study was planned to estimate the combining ability and heterosis among the maize germplasm lines for grain yield and other desirable traits and determine heterotic groups of germplasm lines. To do this thirty two lines were crossed with two diverse testers in Line x Tester mating design during Rabi, 2018-19 and the resulting 64 F_1 hybrids along with six

checks were evaluated in 10 x 7 alpha lattice design at AICRP (Maize), UAS, Dharwad, during Kharif, 2019-20. Among the parental lines 16 lines recorded significant gca effects in positive direction for grain yield viz., GPM-56(30.88), GPM-18(25.74) GPM-583(22.45), GPM-629(13.75) GPM-629 (13.75 Z) and GPM-16(8.29). For earliness 12 lines showed significant gca effect in desirable negative among them GPM-753 was the earliest (-4.203). For 100 grain weight 20 lines shows gca effect in positive direction and line GPM-583 recorded highest magnitude of gca effect for 100 grain weight (7.89). Among the 64 test hybrids GH-1809 recorded highest grain yield of 101.71 q/ha and was significantly superior over national check NK-6240 by 41 per cent and this was followed by GH-1829 (97.65 q/ha) and GH-1845(93.48 q/ha).The sca effect for grain yield ranged from -22.88 to 22.88 and 20 hybrids recorded sca effects in positive direction. The test hybrid GH-1845 (22.88) recorded highest magnitude of sca effects. Heterotic grouping based on SCA-PY and HSGCA method revealed that out of 32 germplasm lines seven were grouped to heterotic group **A** with GPM-629 and GPM-18 showing significant gca effects for grain yield similarly in heterotic group B which consisted comprised of eight lines with GPM-583 and GPM-56 recording significant gca effects for grain yield. Therefore, these four lines can be inter crossed to get heterotic hybrids to get the heterotic hybrids for grain yield.

I-29 IDENTIFICATION OF HAPLOID MAIZE KERNELS IN ABSENCE OF TYPICAL *NAVAJO* PHENOTYPE EXPRESSION IN INDUCTION CROSSES WITH *R1-NJ*-BASED HAPLOID INDUCER LINES

Khulbe R.K., Pattanayak A. and Pandey V.
ICAR- Vivekananda Parvatiya Krishi Anusandhan Sansthan, Almora
rajesh.khulbe@icar.gov.in

Doubled haploid (DH) technology is growingly becoming an integral component of maize breeding programmes worldwide. The currently popular method of DH development uses *R1-nj* based haploid inducers lines (HILs) and the efficiency of this method is chiefly determined by the accuracy in segregating haploid and diploid seed in generated induction crosses. Though various methods for identifying haploid kernels have been reported, kernel anthocyanin pigmentation (*Navajo* phenotype) based method remains the method of choice on account of being simple and easy to use. However, absence of typical *Navajo* phenotype caused by presence of anthocyanin inhibitor gene/s in some source populations limit use of this method. It is therefore important to look for possibilities of identifying haploid seed in the absence of typical *Navajo* phenotype expression. The material in the present study comprised single-cross hybrid CMVL 55, its maternal parent V 405 and CIMMYT's haploid inducer line TAILP1. From earlier studies, both CMVL 55 and V 405 are known to not express full kernel anthocyanin pigmentation in induction crosses with TAILP1, which greatly reduces the efficiency of haploid seed selection. In the present study, attempt was made to identity haploid seed in the induction crosses of CMVL 55 and V 405 on the basis of kernel pigmentation that is not typical of *Navajo* phenotype. CMVL 55 and V 405 each were pollinated with a mixture of their self-pollen and pollen of TAILP1 to generate induction crosses. The resultant seed in each induction cross was classified into selfed, F_1 and haploid categories on the basis of pigmentation in the lower dorsal region of the kernel and the embryo region. The polidy status of the three classes of seed was confirmed by growing them in the field, which indicated the effectiveness of this method in distinguishing selfed, F_1 and haploid seed in the induction crosses of CMVL 55 and V 405. The applicability of this method needs to be tested on a wider set of genotypes that are known to carry anthocyanin inhibitor gene/s. If found to have a wider applicability, this method would prove useful for deriving DH lines from important source populations that do not exhibit typical *Navajo* phenotype in induction crosses with *R1-nj*-based haploid inducer lines.

I-30 GENETIC VARIABILITY, CHARACTER ASSOCIATION AND PATH COEFFICIENT ANALYSIS FOR YIELD AND YIELD CONTRIBUTING TRAITS IN SWEET CORN

Khulbe R.K., Sharma D., Pattanayak A. and Kant L.
ICAR- Vivekananda Parvatiya Krishi Anusandhan Sansthan, Almora
rajesh.khulbe@icar.gov.in

Sweet corn (*Zea mays* var. *saccharata*) has emerged as an important cash crop in India on account of its shorter growing period and year round demand. It is amenable to processing and preservation and yields green fodder as well. At present only a limited choice of high yielding sweet corn hybrids is available to the farmers and therefore there is a need to widen this range in order to be able to cater to diverse regional and seasonal growing requirements. Higher grain yield is an important breeding objective in sweet corn besides grain quality that includes grain size, colour, texture, flavour and TSS. Selection for yield is often difficult in crop breeding because of its complex architechture, polygenic inheritance and composite nature. Dissection of complex composition of the yield trait therefore is important to understand the relationship among its constitutent traits. In the present investigation, a set of 21 sweet corn hybrids was evaluated for yield and yield contributing traits in a randomized block design (RBD) with three replications. The ears were harvested at early dough-stage and observations on seven traits *viz.,* cob length, cob girth, number of kernel rows, number of kernels per row, shelling percentage, 100-grain weight and grain yield were recorded for assessing genetic variability and performing association and path analysis.. Analysis of variance revealed presence of significant genetic variation for grain yield and its attributes. The relative magnitude of phenotypic coefficients of variation (PCV) was higher than genotypic coefficients of variation (GCV) for all the characters under study indicating environmental influence on the traits. Moderate level of GCV observed for number of kernel rows (11.56%), 100-grain weight (10.03%) and seed yield (17.98%) suggested sufficient variability and thus scope for genetic improvement through selecting for these traits. Cob length, cob girth, number of kernel rows and 100-grain weight exhibited high heritability in the material. High heritability coupled with moderate genetic advance as per cent of mean found for cob length, number of kernel rows and 100-grain weight indicated that direct selection for these traits can be effective for yield improvement. Grain yield exhibited positive and significant correlation with all the traits. The number of kernel rows, number of kernels per row and 100-grain weight had a positive direct effect on total yield per plant. Correlation and path analysis indicated that selection for number of kernel rows, number of kernels per row and 100-grain weight would be more promising for the improvement of grain yield in sweet corn.

I-31 ESTIMATION OF HETEROSIS AND COMBINING ABILITY IN MAIZE (*ZEA MAYS* L.)

Hombaradi P.R.[1], Patil N.L.[2], Kachapur R.M.[1], Talekar S.C.[3] and Harlapur S.I.[1]
[1]AICRP on Maize, MARS, University of Agricultural Sciences, Dharwad
[2] Department of Genetics and Plant breeding, University of Agricultural Sciences, Dharwad
[3]Agriculture Research Station, University of Agricultural Sciences, Mugad
praveenhombaradikrishi@gmail.com

An experiment was conducted to estimate heterosis and combining ability among 67 germplasm lines sourced from IIMR / CIMMYT for grain yield and other desirable traits. The germplasm lines were crossed with two diverse testers (CML-451 and CM-111) in Line x Tester mating design and the F_1 hybrids were evaluated along with checks in 14 x 10 alpha lattice design at AICRP (Maize), UAS, Dharwad, during *Kharif*, 2018-19. The analysis of variance revealed that the hybrids differed significantly among themselves and the contribution of lines towards the total hybrid variance was higher than the testers. Among the parental lines GPM-726 (17.26) recorded significant gca effects for grain yield followed by GPM-22 (13.77) and GPM-119 (11.99). Similarly, for earliness GPM-264 (-3.30) recorded negative gca effect in desirable direction and GPM-28-1 was found promising for number of kernels/ row (5.33) and cob length (2.67) respectively. Estimation of genetic components of variance (GCA to SCA variance) also revealed preponderance of non-additive gene action for grain yield. Standard heterosis for grain yield over local checks GH-0727 and GPMH-1101 varied from - 45.52 to 43.53% and - 46.72 to 31.24% respectively. Test hybrid GH-17149 recorded highest standard heterosis (36.75 %) for grain yield over local checks GH-0727 and GPMH-1101 followed by GH-17173 (31.24%) and GH-17202 (28.26). Hybrid GH-17149 (GPM-225 X CML-451) recorded 87.26 q/ha grain yield and was on par with National check NK-6240. The major yield contributing traits were test weight (31.0 to 38.0g) and cob length (15.3 to 19.0 cm). All the promising hybrids identified in the present study were of high x high gca type. Heterotic grouping by SCA-PY method classified 13 out of 67 germplasm lines to heterotic group A, 25 to heterotic group B and 29 lines to heterotic group AB. From the present study, the lines GPM-726, GPM-751 and GPM-225 and the hybrids GH-17149, GH-17213 and GH-17179 were found to be promising. The line with highest gca in heterotic group A (GPM-618) can be crossed with lines in heterotic group B (GPM-751, GPM-25, GPM-635 and GPM-721) to develop heterotic hybrids. Lines within heterotic group AB can be crossed among themselves to develop population to derive inbred lines.

I-32 IDENTIFICATION OF STABLE AND HETEROTIC MAIZE HYBRIDS ACROSS DIVERSE AGRO-ECOLOGICAL ZONES OF KARNATAKA

Kachapur R.M.[1], Praveen H.[1], Motagi B.N.[2], Talekar S.C.[3]and Harlapur S.I.[1]
[1]AICRP on Maize, MARS, Dharwad
[2] Department of Genetics and Plant Breeding, AC, Vijayapur
[3]Agriculture Reasearch Station, Mugad
rajashehekhar.kachapur@gmail.com

Maize is an important cereal crop after rice and wheat in India. It is grown on an area of 9.0 m ha with average productivity of 2.8 t/ha which is half the way mark to the global maize productivity of 5.5 t/ha. Hence, there is tremendous scope to enhance the maize productivity in India with lot of challenges ahead in the form of productivity constraints. Crop improvement efforts interms of identification of hybrids is continuous efforts. In the present study twelve promising maize germplasm were crossed with two testers CML-451 and CM-111 in Line x Tester mating design and the 24 hybrids generated were evaluated along with checks during Kharif,2018 at Dharwad (Northern transitional zone) and Vijayapur (Northern dry zone). Each entry was raised in two rows of three replications of 4 mtr length in RBD design. Among the twenty six hybrids at Dharwad location the National check hybrid NK-6240 was the highest yielding hybrid (84.3 q/ha) followed by the test hybrid GH-17147 (81.0 q/ha) at Viajaypur test hybrid GH-17184 (109.3 q/ha) followed by GH-17146 (104.7 q/ha) whereas the national check hybrid NK-6240 recorded (80.6 q/ha). To identify the best hybrid across the locations, the hybrids were ranked based on their mean grain yield at each of the location separately and rankings were averaged instead of mean grain yield. Accordingly across the locations the test hybrid GH-17149 (GPM-119 X CML-451) was the best consistent hybrid with a mean grain yield on 77.2 q/ha. This was followed by test hybrid GH-17148 (GPM-225 X CM-111) and NK-6240 which had the same average ranking but however they recorded a grain yield of 85.9 q/ha and 82.5 q/ha respectively. The local check hybrid GPMH-1101 even though recorded 79.6 q/ha, but as per average of the ranks from tow location it was found to inconsistent. However, the heritability of the two locations Dharwad and Vijayapur were at 35 and 31 per cent respectively for grain yield.

I-33 DETERMINATION OF HETEROSIS AND COMBINING ABILITY IN MAIZE (*ZEA MAYS* L)

Shankar M.[1], Shahi J.P.[1], Singh R.[1], Singamsetti A.[1] and Devesh A.[1]
[1]Department of Genetics and Plant Breeding, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi
agrishankar11@gmail.com

Determination of heterosis and combining abilities of parental lines is essential in choosing the inbred lines and in deciding breeding approach for maize hybrid production. A line × tester investigation was carry out in maize involving 12 inbreds and 3 testers for grain yield and its components to find out the general combining ability (GCA) and specific combining ability (SCA) effects as well as the heterosis. Highly significant genotypic differences were observed among the studied genotypes. GCA and SCA variance for100-kernels weight, yield per plant and number of kernels per row were observed significant, which showed presence of additive as type of gene action for these traits. The ratio of SCA and GCA variances were high for the all studied traits that indicated the prevalence of non additive type of gene action. Standard heterosis ranged from - 27.17 to 27.32%; -10.23 to 23.32%;-11.27 to 23.27%; -10.81 to 20.72% -16.13 to 10.35% and -13.64 to 6.78%; for grain yield per plant, number of rows per ear, number of grains per row, 100-kernel weight, ear diameter and ear length, respectively. The lines CAL1422, CAL1427, ZL154350, CIL12161 and CAL1423 showed significant and positive GCA effect and concurrently possessed high mean value demonstrating that the per se performance of the parents could prove as an valuable indicator for combining ability. The crosses showed significant SCA effects involved high × high, low × high, high × low, average × low and low × low general combining parents. The cross combinations with significant and positive SCA effect with high mean value might be used for

developing high yielding hybrids. The insight on the nature of gene action with respective variety and traits might be used depending on the breeding objectives.

I-34 ASSESSMENT OF GENETIC DIVERSITY IN SINGLE CROSS HYBRIDS OF MAIZE (*ZEA MAYS* L.)

Karad S.R.[1], Kumhar S.D.[2] and Khot G.G.[3]
AICRP on Maize, Mahatma Phule Krishi Vidyapeeth, Kolhapur
sunil_r_karad@yahoo.co.in

A set of sixty normal Maize (*Zea mays* L.) single cross hybrids were evaluated with four checks for eleven morphological characteristics to study nature and magnitude of genetic variability using Mahalanobis D^2 statistics during *kharif* 2019. Wide range of variation was observed for all the eleven characters under study. The analysis of variance exhibited significant difference among the hybrids for all the characters indicating substantial degree of variability. Among the sixty single cross hybrids the test entries QMH-1819 (97.43 q/ha), QMH-1834 (88.09 q/ha), QMH-1859 (87.75 q/ha), QMH-1815 (85.18 q/ha) and QMH-1860 (83.99 q/ha) recorded statistically higher grain yield than the highest yielding check Bio 9682 (70.50 q/ha). The 31 and 13 hybrids showed higher grain yield than the best check and trial mean, respectively. The plant height ranged from 115 to 178 cms, while ear height ranged between 30 to 65 cms indicating wide range of variability. The days to 50% silk recorded range from 51 to 62 however days to 75% dry husk ranged between 90 to 103 days. According to grain type and colour the sixty hybrids divided into nine category *i.e.* OYSF 20, OYD 01, OSF 11, YSF 03, OYSD 16, CYSD 01, WSF 03, WSD 07 and OYF 01. In overall, D^2 analysis suggested QMH-1819 (97.43 q/ha), QMH-1834 (88.09 q/ha), QMH-1859 (87.75 q/ha), QMH-1815 (85.18 q/ha) and QMH-1860 (83.99 q/ha) were the most diverse single cross hybrids could be utilized for further study in breeding programme to enhance the productivity of maize.

I-35 GENOTYPE × ENVIRONMENT INTERACTION AND STABILITY PARAMETERS IN NEW SINGLE CROSS MAIZE HYBRIDS (*ZEA MAYS* L.)

Kumbhar S.D., Karad S.R., Pilane M.S., Patil S.A. and Khot G.G.
AICRP on Maize, Mahatma Phule Krishi Vidyapeeth, Kolhapur

Maize is the second most important cereal crop in the world in terms of acreage and is called the 'Queen of Cereals'. The current maize production scenario highlights presence of hybrid maize at about 65-70 percent acreages and most of it accounts for feed and industrial grade Maize. In the recent years, although the rate of adoption of hybrids has slowed down, but farmers continue to replace traditional cultivars/old hybrids with the newer higher-yielding hybrid varieties. Many hybrids have been developed and released by public and private sector. Consistency of a hybrid over wide range of environment is primary consideration in breeding programme. The present study comprising of new hybrids was therefore attempted to understand the G x E interaction and consistency in performance through stability analysis in thirteen newly developed single cross maize hybrids along with four checks. These entries were evaluated in randomized block design with three replications at varied climatic nine locations (*viz*. Kolhapur, Pune, Rahuri, Gadhinglaj, Dhule, Savalvihir, Aurangabad, Buldhana and Parbhani) in Maharashtra during *Kharif* 2019.The mean

squares due to genotype and genotype x environment interaction were found significant. The stability analysis conducted through Eberhart and Russell Model recorded non-significant bi values for all the entries under study. Nine entries recorded non-significant S^2di values. Simultaneous consideration of stability parameters for grain yield indicated that among the test hybrids QMH 1617 with orange yellow semi-dent grain and late maturity; QMH 1701 with orange yellow semi-flint grain, QMH 1716 with white semi-flint grain and QMH 1571 with orange yellow semi-flint grain were stable over the test environments. The hybrid QMH 1617 recorded 86.27 q/ha grain yield and was superior to all the checks under study and is suitable for cultivation in Maharashtra.

I-36 IDENTIFICATION OF POTENTIAL PARENTAL LINES FOR SINGLE, THREE-WAY AND DOUBLE CROSSES IN MAIZE (*ZEA MAYS* L.)

Sumalini K.[1], Pradeep T. [2] and Sravani D.[3]
[1]Agricultural Polytechnic College, Professor Jayashankar Telangana State Agricultural University, Kampasagar
[2]Seed Research and Technology Centre, ARI, Professor Jayashankar Telangana State Agricultural University, Rajendranagar
[3]Agricultural Research Station, Professor Jayashankar Telangana State Agricultural University, Karimnagar
sumalinikatragadda@gmail.com

A series of single, three way and double crosses of maize developed by involving seven inbred lines through half diallel were evaluated along with private/public hybrids for yield and yield contributing traits in a balanced lattice design at three environments during *kharif*, 2015. Combining ability studies revealed that in triallel analysis, good general combiners of diallel analysis had significant and desirable 1-line general line effects of first and second kind for days to 50% pollen shed, days to 50% silk emergence, kernel rows ear^{-1}, kernels row^{-1}, shelling %, 100-grain weight, fodder yield and grain yield and for days to maturity, plant height, ear height, ear length, ear diameter good general combiners of diallel had either significant desirable 1-line general line effects of first or second kind indicating that good general combiners of diallel could be used both as grandparents (hi) and/or immediate parents (gi). In quadriallel analysis, good general combiners of diallel had expressed desirable 1-line general line effects for all the studied traits indicating general combiners of diallel must be involved as one of the four parents in double crosses. In triallel analysis, for majority of the yield and yield contributing traits good specific combiners were involved as grandparents/ half parents in all of the significant 2-line specific effects of first kind (dij) and second kind (sij) in desirable direction. Similarly, few of the three-line effects were the combination of a good specific combiner of diallel with a good general combiner suitable as immediate parent for majority of the traits. In case of grain yield, good specific combiners of diallel were involved as grandparents or half parents in all significant 2-line and 3-line interaction effects except BML-10 × BML-6 in 2-line interaction effect of second kind (sij) and BML-13 × BML-10 in 3-line interaction effects (tijk). BML-51, a good general combiner for grain yield was involved as one of the parent in all significant 3-line effects either as grand parent or immediate parent except (BML-32 × BML-10) × BML-7. In quadriallel analysis for all the traits studied except days to maturity, either one or two or all of the three crosses of tij, ti.j. and sij interaction effects were identified as good

specific combiners of diallel analysis. Good specific combiners of diallel were involved as grandparents in 3-line and 4-line interaction effects of lines due to particular arrangement *i.e.* tij.k effects for majority of the traits and for all the studied traits except shelling percentage in tij.kl effects. However 3-line and 4-line interaction effects irrespective of arrangement *i.e.* sijk and sijkl effects, respectively had good specific combiners of diallel either as grandparents and/or half parents for all the studied traits. Good specific combiners of diallel *viz.,* BML-51 × BML-6 as half parents in three-way crosses, BML-51 × BML-7 as half parents in double crosses, BML-51 × BML-14, BML-32 × BML-13 and BML-32 × BML-6 as half or grandparents in three way and double crosses resulted in high yielding climate resilient hybrids.

I-37 ESTIMATION OF GENETIC DIVERSITY AMONG NEWLY DEVELOPED WINTER MAIZE INBRED LINES

Singh S.B.[1], Chikkappa G. Karjagi[2], Kumar S.[1], Kumar K.[2], Yathish, K.R[3]., Jat B.S.[4], Kasana R.K.[1], Kumar A.[1] and Rakshit S.[4]

[1]Regional Maize Research and Seed Production Centre, ICAR –Indian Institute of Maize Research, Begusarai

[2]Delhi Unit Office, ICAR –Indian Institute of Maize Research, New Delhi

[3]Winter Nursery Centre, ICAR –Indian Institute of Maize Research, Hyderabad

[4]ICAR –Indian Institute of Maize Research, Ludhiana

singhsb1971@rediffmail.com

Maize (*Zea mays* L.), the queen of cereals, holds unmatched fitness across diverse environments due to the high level of plasticity in its genome. Maize is gaining exponential rise in global demand even over the wheat and rice reflecting the substantial growth of maize in developing as well as industrial countries. Exploitation of hybrid vigor in maize has gained much significance in view of tremendous increase in its yield but still it demands the continuous development of better than the best hybrids to fulfill these rising demands in terms of yield as well as quality. Looking into the above facts, genetic diversity study at the morphological as well as molecular level with the help of forty polymorphic markers was made using 140 newly developed and 13 parental inbreds of released maize hybrids at Regional maize Research & Seed Production Center ICAR-IIMR), Begusarai, Bihar during Rabi, 2018-19. This study was conducted to understand the diverse nature among these lines and subsequently to use the desirable diverse parents in maize breeding program to produce superior hybrids, segregating populations with high variability and introgression of desirable traits/genes. D square study revealed the twenty clusters among which three clusters comprised 92, 21 and 23 genotypes while 17 genotypes falls in 17 different clusters individually. The highest inter-cluster distance was found between the cluster 17 & 19 (IMLSB-955-1 & IMLSB-2094) followed by cluster 13 & 17 (IMLSB-423-1 & IMLSB-955-1) and 14 & 17 (IMLSB-81-1 & IMLSB-955-1). Among the first three clusters highest inter-cluster distance was found between cluster 2 & cluster 3 and highest intra-cluster distance was observed within cluster 2. This reveals that the crosses among these distant genotypes may harness greater level of heterosis. Molecular diversity study with the help of 40 polymorphic markers which displayed clear size differences and total of 873 alleles were generated through these primers with an average polymorphism information content value of 0.8367. The primer *bnlg* 1614 and *bnlg*1642 was found as the best marker for identification of genotypes as revealed by PIC values (0.9838 & 0.9737 respectively). The Jaccard's dissimilarity index showed the highest value of 1.00 among the genotypes IMLSB-274-1 & LM-16 followed by IMLSB-123-1 & LM-16 (0.981), IMLSB-119-2 & LM-14 (0.978), IMLSB-114-1 & HKI-1128 (0.978) and IMLSB-106-2 & HKI-1128 (0.978). The Jaccard's dissimilarity index classified the total genotypes in two major clusters and eight sub clusters. The high D square distance found among the genotypes IMLSB-955-1 & IMLSB-2094, IMLSB-423-1 & IMLSB-955-1 and IMLSB-81-1 & IMLSB-955-1 also recorded high Jaccard's dissimilarity coefficient value of 0.906, 0.798 & 0.840 respectively. These diverse genotypes can be used in further breeding program in the development of high yielding single cross maize hybrids as well as segregating population with high variability and introgression of desirable traits/genes.

I-38 DIVERSIFICATION OF QPM GERMPLASM THROUGH MAGIC APPROACH

Kumar R.[1], Das A.K.[1], Singh S.B.[2], Neelam S.[3], Chaudhary D.P.[1], Kaur Y.[1], Suby S.B.[4], Aggarwal S.K.[1] and Rakshit S.[1]

[1]ICAR-Indian Institute of Maize Research, Ludhiana

[2] Regional Maize Research & Seed Production Centre, ICAR - Indian Institute of Maize Research, Begusarai

[3]Winter Nursery Centre, ICAR- Indian Institute of Maize Research, Hyderabad

[4] Delhi Unit office, ICAR- Indian Institute of Maize Research, New Delhi

Maize is considered as 'Queen' of cereals, however it is deficient in two essential amino-acids i.e. lysine and tryptophan. Quality Protein Maize (QPM) has double the amount of tryptophan and lysine content as compared to normal maize. The QPM germplasm has narrow genetic base thereby difficult to improve for high grain yield. The QPM germplasm needs to be diversified through different means like Mass Assisted Selection (MAS) and Multi-parent Advanced Generation Inter-cross (MAGIC) approach. The present study was conducted keeping in mind the diversification of QPM germplasm using MAGIC approach. A set of 48 inbred lines (24 QPM and 24 normal lines) were selected on the basis of perse performance and these lines were crossed with two diverse testers *i.e.* LM 13 & LM 14 to generate the information on heterotic grouping and simultaneously diversity studies were also carried out using SSR markers. The dendogram clearly showed that the QPM and normal germplasm is falling in different clusters. Based on heterotic grouping data and diversity analysis the lines were selected for making cross combinations within heterotic groups. The normal lines of one group were crossed with QPM lines of the same group and vice-versa. Four crosses were made in similar fashion *viz*., for heterotic group A, DML 2052 × DQL 2111 and DML 1837 × DQL 2303and for heterotic group B, DML 1596 × DQL 2180 and DML 1812 × DQL 2290. The two crosses made for group A will again be crossed among themselves similarly in case of group A and then new lines will be synthesize. Desirable QPM lines will be advanced to next generation based on the biochemical data and these lines after reaching S6-S7 stage, will be tested for *per se* performance and then best lines will be used for crossing programme for development of new hybrids.

I-39 ESTIMATION OF HETEROSIS FOR YIELD AND QUALITY PARAMETERS IN MAIZE (*ZEA MAYS* L.)

Gurjar N.R., Dadheech A., Kumar S. and Badiya V.
Department of Plant Breeding and Genetics, Rajasthan College of Agriculture
Maharana Pratap University of Agriculture and Technology, Udaipur

Maize is amazing crop which is C_4 plant and it is an important cereal crop belonging to the grass family, Poaceae and is a native to South America. In Rajasthan area under cultivation during *Kharif* is highest among other maize growing states. Thirty nine hybrids of maize were developed through Line x Tester mating design using three tester and thirteen inbreds to study heterosis in maize. Parents, hybrids along with three standard checks namely, Pratap Hybrid Maize-3(PHM-3), PMH-3 and PM-9, were evaluated during *kharif* 2018 for 14 characters at instructional farm Rajasthan College of Agriculture, Udaipur, Rajasthan. The mean sum of squares of hybrids, lines and testers, were significant for all the traits except days 75 per cent brown husk of lines, While days to 50 per cent tasseling, days to 50 per cent silking, days 75 per cent brown husk, ear length and ear girth of testers. A perusal of estimates of economic heterosis for grain yield per plant revealed that five hybrids L_7 x T_2 (14.47%), L_3 x T_3 (11.19%), L_6 x T_2 (10.44%), L_6 x T_1 (9.93%)and L_9 x T_3 (9.88%) depicted positive significant economic heterosis for grain yield per plant over the best check Pratap Hybrid Maize-3**.** Among the five best hybrids having higher estimates of significant positive economic heterosis for grain yield per plant *viz.*, L_7x T_2, L_3 x T_3, L_6 x T_2**,** L_6 x T_1 and L_9 x T_3 (Table 5.1). Hybrid (L_6 x T_2) also exhibited higher estimates of significant positive economic heterosis for oil content.These crosses will be considered for finding transgressive segregants in segreganting generation to develop a maize variety with quality improvement.

I-40 ANALYSIS OF GENETIC DIVERSITY IN QPM INBRED LINES

Lenka D., Swain D., Kanungo P. and Jagadev P.N.
Department of Plant Breeding and Genetics, Odisha University of Agriculture and Technology, Bhubaneswar

The knowledge of genetic diversity among maize inbreds is essential for cross combinations between genetically diverse parents which are likely to produce high heterotic effect. Fifty inbred lines of quality protein maize (QPM) were studied for genetic divergence and resemblance through molecular characterization approach. These fifty QPM inbred lines were evaluated in RBD with two replications during *Rabi* and analysis of variance revealed highly significant differences among the inbred lines for all the 15 characters under study indicating existence of wide genetic variations. Multivariate analysis of genetic diversity in the 50 QPM inbred lines for 15 quantitative traits led to their grouping into 11 clusters on the basis of Tocher's method indicating the presence of genetic diversity among the genotypes. Days to 75% dry husk contributed maximum, accounting for 29.9%, to genetic divergence (29.9%) followed by days to 50% tasseling (15.2%). Based on inter-cluster average D^2-values, hybridisation between QPM inbreds of diverse cluster pairs such as cluster IV and X, IV and IX, IV and VII could be useful for obtaining high heterotic hybrids. Molecular characterization of selected 20 QPM inbreds with two SSR markers (phi057 and umc1066) with PIC value of 0.55 and 0.74 led to grouping of the inbreds into three major clusters with Cluster III was the major cluster with 18 genotypes and it was further be sub-divided into two sub-clusters with cluster-IIIa having 13 genotypes (VL1052388, VL1016422, VL109273, VL1016399, VL1016590, VL109288, VL1113821, VL109266, VL1017054, VL1016453, VL109412, VL109476 and VL109475) and cluster-IIIb with 5 genotypes (VL1016414, QPM 10-13-1, QPM 8-3-2, QPM 11-7-1 and QPM 7-3-2). Two inbreds i.e., VL1016548 and VL1017524 formed separate outer groups indicating their diversity from rest of the genotypes.

I-41 EVALUATION OF YIELD STABILITY FOR GRAIN YIELD IN MAIZE HYBRIDS USING AMMI ANALYSIS UNDER DIFFERENT AGRO-ECOLOGIES OF ODISHA

Swain D.[1], Lenka D.[1], Das S.[1] and Tripathy S.K.[2]
[1]Department of Plant Breeding and Genetics, [2]Department of Agricultural Biotechnology,
Odisha University of Agriculture and Technology, Bhubaneswar

Twenty eight maize experimental hybrids along with two check hybrids were evaluated in a randomised complete block design with two replications under rainfed condition during *Kharif* at six locations spread over different agro-climatic zones of Odisha varying with respect to soil, altitude and climatic conditions to identify stable maize hybrids for grain yield. Pooled analysis of variance indicated considerable variation among genotypes, environments and genotype x environment (G x E) interaction for grain yield. Thirteen experimental hybrids produced higher grain yield than general mean (82.4 q/ ha) and three hybrids (ZH17210, ZH17223 and ZH159) had significantly higher grain yield as comparison to the best check, P 3502 (91.7 q/ ha) across the environments. The significance of G x E interaction revealed that G x E interaction had remarkable effect on the performance of genotypes in different environments. The grain yield was subjected to Additive Main Effects and Multiplicative Interaction (AMMI) for stability analysis. The AMMI analysis of variance indicated that environment effects accounted for 54.4% of total variation in the sum of square for grain yield followed by G x E interaction (30.9%) and genotypes (14.7%). The first three Interaction Principal Component Axis (IPCA I, IPCA II and IPCA III) of G x E interaction were also highly significant accounting 39.8%, 24.7% and 19.5%, respectively of the total variation in G x E interaction for grain yield. Based AMMI stability analysis four experimental hybrids i.e., VH113014, ZH17229, VH151139 and ZH161418, which showed minimum interaction (IPCA I absolute values close to zero) were found to be stable for grain yield and among these hybrids, ZH161418 followed by VH151139 and ZH17229 had higher grain yield than general mean (82.4 q/ ha) which might be considered as the most suitable with good general adaptation. In contrast, the hybrids e.g., ZH17210, ZH17223 and ZH 17224 had higher yield but with considerable magnitude of interaction (IPCA I) indicating their adaptation to specific environments. Koraput was found to be favourable environment and Bhanjanagar was a poor environment for overall productivity of maize hybrid, while Bhubaneswar location with IPCA I and IPCA II scores close to zero seems to have minimum environmental interaction for grain yield in maize hybrids.

I-42 UNDERSTANDING TRAIT AND GEOGRAPHIC DIVERSITY AMONG MAIZE HYBRIDS –THROUGH DIVERSITY INDICES USING DIVA-GIS AND MAXENT

Sunil N.[1], Sivaraj N., Yathish K.R.[1], Vinodhana K.[3], Kachhapur R.M.[4], Sravani D.[5], Bhadru D.[5], Ramesh P.[1], Dhandapani A.[6] and Rakshit S.[1]
[1]ICAR-Indian Institute of Maize Research, Ludhiana
[2]ICAR-National Bureau of Plant Genetic Resources Regional Station, Hyderabad
[3]Tamil Nadu Agricultural University, Coimbatore
[4]University of Agricultural Sciences, Dharwad,
[5]Professor Jayashankar Telangana State Agricultural University, Hyderabad
[6]ICAR-National Academy of Agricultural Research Management, Hyderabad
sunilneelam9@gmail.com

Under the AICRP on maize, 63 diverse hybrids, involving both public and private sector, were evaluated /tested in NIVT Late trial during *Kharif* 2018. The data *viz*. plant height, cob height, days to 50% pollen shed, days to 50% silking, days to 75% maturity and cob weight from four diverse geographic locations (centres) of the peninsular region *viz.* Coimbatore, Dharwad, Karimnagar and Hyderabad were analysed for diversity and richness indices using DIVA-GIS software. The objective was to identify the trait (s), which showed more diversity or richness among the hybrids and secondly to identify the centre- geographical region which was more efficient in bringing about the diversity and richness in the hybrids. Ecological niche modelling using Maximum Entropy method was analysed to identify the potential regions for growing the elite maize hybrids. The study will help in understanding the diverse hybrids and also the geographical regions (climatic conditions) for resolving the diversity among the hybrids better and also those regions which are better suited for the cultivation of these hybrids.

I-43 RECONSTITUTION OF BIOFORTIFIED MAIZE HYBRIDS POSSESSING FAVOURABLE ALLELES OF *Β-CAROTENE HYDROXYLASE, LYCOPENE*-Ε-*CYCLASE* AND *OPAQUE2* FOR COMBINING HIGH PROTEIN, MINERALS, TRYPTOPHAN AND PROA IN MAIZE

Sharma S.[1], Singh J.[1], Kaur H.[2], Vikal Y.[1], Gill G.K.[2], Kumar A.[3], Sharma S.[2] and Hossain F.[4]
[1]School of Agricultural Biotechnology, [2]Department of Plant Breeding and Genetics, Punjab Agricultural University, Ludhiana
[3]Regional Research Station, Gurdaspur, Punjab Agricultural University, Ludhiana
[4]ICAR-Indian Agricultural Research Institute, New Delhi
shikhapanjolia@gmail.com

Traditional yellow maize though contain high kernel carotenoids, but the concentration of provitamin A is quite low (<2µg/g) as compared to recommended level (15µg/g). Enriching corn with vitamin A, will serve and assure the human population feeding on maize with enriched nutrititve factor providing solution for blindness and major diseases caused by vitamin A. Here, we report the development of nutritionally enriched PMH1 and Buland hybrids, using marker assisted introgression of *β-carotene hydroxylase, lycopene*-ε-*cyclase* and *opaque2* favourable alleles in elite inbred lines viz. QLM11, QLM12, QLM13 and QLM14. These inbreds are parental lines of high yielding commercial maize hybrids in North India viz. Buland and PMH1 respectively. For this purpose, F_1, BC_1F_1, BC_2F_1, $BC_2F_2$and BC_2F_3 plants were developed using β-carotene rich CIMMYT (HP-467-15) line as donar parent and QLM inbred lines as the recurrent parents. The QLM inbred lines was crossed to HP-467-15 to produce $F_{1s}$and their testing for heterozygosity was done using gene-specific markers. Heterozygous plants with high recovery of the recurrent parent genome obtained functioned as males were then backcrossed to recurrent female parent twice to produce BC_1F_1 and BC_2F_1 in 2015 & 2016 respectively and were subjected to foreground, background and phenotypic selection. Furthermore, the selected heterozygous BC_2F_1 plants from both crosses were selfed to obtain BC_2F_2 plants, which were then selected for the target genes and selfed to generate the BC_2F_3, BC_2F_4 and BC_2F_5 populations. The improved lines have good agronomic performance and possessed high protein (4.40-9.76), tryptophan (0.60-3.84)and β-carotene (9.21-12.44 μg/g) content. The reconstituted hybrids showed an average of 4.5-fold increase in proA with a range of 9.25–12.88μg/g, compared to original hybrids (2.14–2.48μg/g). Similarly, the agronomic traits viz. plant architecture, ear and grain characteristics of improved versions of both inbreds and hybrids were observed when evaluated with their respective original versions. Mean protein (11.76%) and tryptophan (4.74%) of the improved hybrids were *at par* with the original versions (protein: 6.43%, tryptophan: 1.89%). Improved hybrids also possessed similar grain yield potential with their original versions evaluated at two locations. These biofortified high yielding maize hybrids, rich in proA, tryptophan and percent protein possess great potential to simultaneously alleviate Vitamin A deficiency and protein-energy malnutrition across the world.

I-44 EVALUATION OF MAIZE HYBRIDS FOR STABILITY ACROSS ENVIRONMENTS USING GGE BIPLOT AND AMMI ANALYSIS

Kumar S.[1], Patne N.[2], Vivek B.S.[3] and Satyanarayana P.V.[4]
[1]AICRP on Maize, Acharya N.G. Ranga Agricultural University-Agricultural Research Station, Peddapuram, East Godavari District
[2,3]International Maize and Wheat Improvement Center -Asia, Hyderabad
[4]Associate Director of Research, Acharya N.G. Ranga Agricultural University-Regional Agricultural Research Station, Maruteru, West Godavari District
injetisudhirkumar@gmail.com

Under climate change scenario cultivation of genotypes non-adapted to the cultivation region greatly influences yield. Adaptability and stability of genotypes will determine their superiority which can be best assessed by evaluating the cultivars in different environments and ecological regions. Identification of promising maize hybrids for their adaptability and stability help in choosing superior maize hybrids for production which depends on the extent of presence of genotype×environment interaction (GEI). Several stability statistics may be used to partition GEI which include regression analysis, multivariate analysis, cluster analysis, genotype main effect plus genotype × environment (GGE) biplot and additive main effect and multiplicative interaction (AMMI). The most commonly used statistical analysis for the interpretation of GEI based on the use of biplots of AMMI model. A study was conducted in which fifty six yellow maize hybrids were evaluated for grain yield stability across three diversified environments of Andhra Pradesh *viz*., Vizianagaram (E1), Peddapuram (E2) and Reddipalli (E3) representing three agro ecological zones *viz*., North coastal, Godavari and scarce rainfall zones respectively. Combined analysis of variance based on AMMI analysis has shown highly significant differences for environments, genotypes by environment interactions. Grain yields of hybrid maize genotypes were significantly affected by genotype by environment interaction which explained 43.7

percent of the total yield variation followed by environments which accounted for 38.0 per cent. Partitioning of GGE through GGE Biplot analysis showed the first two interaction principal component axes explained about 99.99 percent (57.43% and 42.56% by IPCA1 and IPCA2 respectively) of the grain yield variation due to genotype and genotype by environment interaction (GGE). Contribution of 17.43% by the genotypes indicates least contribution of genotypes to the total variation in the multi environment trials. The mean grain yield over environments ranged from 6234 kg/ha (CAH1521) to 3749 kg/ha (CAH1542) with a grand mean of 5194 kg/ha. Out of fifty six hybrids, 30 hybrids had above the mean average yields. The GGE biplot analysis has shown CAH1628 and CAH1639 as most stable hybrids and can be considered as adaptable to all the environments. The present study revealed Peddapuram as most discriminating environment among the three and most representative due to its longest distance from the origin of the biplot. Thus the analysis identified best environment in which maize hybrids will have optimal performance. Genetic differentiation of experimental hybrids is best demonstrated in the representative environments.

I-45 ASSESSMENT OF MORPHO-GENETIC DIVERSITY AND TRAIT ASSOCIATION IN MAIZE (*ZEA MAYS* L.) INBRED LINES

Vinodhana K., Ravikesavan N.R. and Prakash R.
Department of Millets, Centre for Plant Breeding and Genetics,
Tamil Nadu Agricultural University, Coimbatore

Maize (*Zea mays* L.) is one of the economic crops of global importance. To develop high yielding hybrids in maize, the development and evaluation of inbreds form the major thrust area of the plant breeding programme. In view of the above, 50 maize inbred lines along with the five checks UMI 1200, UMI 1201, UMI 1205, UMI 1210 and UMI 1230 were raised under Augmented Block Design in the experimental fields of Department of Millets, Tamil Nadu Agricultural University, Coimbatore during *kharif* 2018 to study the nature and magnitude of genetic divergence for grain yield and its component characters to provide a basis for selection of parents in hybridization programme. The data of sixteen different morphological and quantitative traits were subjected to principal component analysis and to study the clustering pattern and simple association between traits. The association analysis showed positive and highly significant correlation of grain yield/plant with cob length (0.67), cob diameter (0.63), cob weight (0.97), number of kernels/row (0.52), hundred seed weight (0.57) and shelling percentage (0.49). Principal component analysis revealed that the first five PCs with Eigen value >1 contributed 75.19 per cent of total variability among the inbred lines for 16 morphological traits. The PC I contributed maximum towards the variability (29.95%) followed by PC II (20.13%), PC III (9.6%), PC IV (8.2%) and PC V (7.28). The most important characters in PC I were due to variations among the inbred lines for grain yield/plant, cob weight, cob length, cob diameter, hundred seed weight, number of kernels/row and shelling percentage which showed positive contribution towards divergence. Cluster analysis distributed the inbreds into 4 clusters indicating their broad genetic base of which cluster I was the largest containing 23 inbreds followed by cluster III (20 inbreds), cluster IV (9 inbreds) and cluster II (3 inbreds). The inbred lines grouped in the cluster I was identified for superior grain yield and its attributing traits suggesting their use in breeding programmes for the exploitation of heterosis for the desirable yield traits.

I-46 IDENTIFICATION OF ELITE PARENTS AND HYBRIDS THROUGH COMBINING ABILITY ANALYSIS IN SWEET CORN (*ZEA MAYS* L. *SACCHARATA)*

Ravikesavan R., Niji M.S., Ganesan K.N. and Vinodhana N.K.
Department of Millets, Centre for Plant Breeding and Genetics,
Tamil Nadu Agricultural University, Coimbatore

Sweet corn (*Zea mays* L. *saccharata*) production in India is recently increasing mainly due to the higher profit. Keeping in view the growing importance of sweet corn in India, the study was undertaken to find out the desirable parents and superior hybrid combinations based on combining ability estimates and the degree and direction of association between the yield and component traits. The investigation was carried out with 7 lines and 7 testers which were crossed in Line x Tester mating design. The resulting 49 crosses along with parents and standard checks were evaluated in Randomised Block Design. The data were collected on eighteen yield and yield contributing characters and five quality traits. Combining ability analysis revealed the predominance of non-additive gene action for most of the traits studied except days to tasseling, days to 50% tasseling, anthesis silking interval and iron content. The lines WNC 12068-2 and SC 11-2 and the testers 951-7 and DMSC 24 were identified as desirable parents for developing hybrids with improved yield and quality traits due to high *per se* performance coupled with high *gca* effects for yield and majority of the yield attributes as well as total sugar content. The hybrids *viz.,* SC 11-2 x 951-7, WNC 12039-1 x 951-7 , SC 11-2 x DMSC 20, WNC 12069 x DMSC 36, SC1107x DMSC 36, WNC 12068-2x WNDMRSCY 19 R 773 and SC1107x DMSC 24 recorded high *per se* performance and significant *sca* effects for green cob yield. Highly significant positive standard heterosis over the check Sugar 75 was registered by the hybrids SC 11-2 x 951-7 (19.09%), WNC 12039-1 x 951-7 (9.27%) and SC 11-2 x DMSC 20 (8.35%). Based on high *per se* performance, *sca* effect and heterosis for yield and contributing traits, the hybrid SC 11-2 x 951-7 was identified as the best hybrid followed by WNC 12039-1 x 951-7. These crosses are valuable and could be used in corn breeding programs in order to achieve high yielding and quality combinations. The hybrids identified can be tested under varied environments to test their stable performance for green cob yield and sugar content.

I-47 DETECTION OF SNPS IN KRN RELATED GENES AMONG SUB-TROPICAL MAIZE (*ZEA MAYS* .L) INBRED LINES

Mukri G.[1], Gadag R.N.[1], Bhat J.S.[1], Shilpa K.M.[1] and Gupta N.[2]
[1]ICAR-Indian Agricultural Research Institute, New Delhi
[2]ICAR- National Institute for Plant Biotechnology, New Delhi
ganapati4121@gmail.com

Genetic dissection of high KRN trait have under taken by several workers and identified number of locus which controls the trait. Fine mapping of QTL controlling KRN, TILLING also resulted in identification of underlying genes. Unfortunately all these studies are imposed on temperate maize genotypes which are otherwise difficult to use them directly in Indian maize breeding program. There is no information available in sub-trophical maize lines in which Indian maize breeding program is interested. Hence study was planned to understand the allelic variation for KRN related genes among sub-tropical maize lines. Amplicon sequencing of four genes *viz., fea4, kn1, fea2 and cg1* were undertaken in four genotypes *viz*., 6-1810040, 21-1810123, 11-1810068 and 34-1810203. Among the genotypes under study, 6-1810040 and 21-1810123 had 10 KRN (low KRN) and 11-1810068 and 34-1810203 had 22 KRN (high KRN). Reference sequence for the genes was taken from maize GDB (www.maizegdb.org) and used it for multiple sequence alignment through *cluster omega* and *snapgene* software. Gene structure display server 2.0 (GSDS) was used to understand the exonic and intronic region of gene in which SNPs are present. Only SNPs present in the exonic regions were taken for its translational changes by using *Expasy* software. The genotypes 6-1810040 and 21-1810123 with low KRN had 14 and 13, 6 and 6, 14 and 2, 9 and 8 SNPs for *kn1, fea2, fea4* and *cg1* respectively. However, the genotypes 11-1810068 and 34-1810203 with high KRN had 17 and 9, 5 and 8, 2 and 7, 8 and 10 SNPs for *kn1, fea2, fea4* and *cg1* respectively. Due to the occurrence of novel SNPs in *cg1 of* 6-1810040, 21-1810123, 11-1810068 and 34-1810203 have *serine* in place of *proline* at 367 positions and isoleucine in place of methionine at 370 positions as compared to the reference sequence. These information can be further validated both qualitative and quantitative measures.

I-48 EVALUATION OF QUALITY PROTEIN MAIZE HYBRIDS SUITABLE FOR SOUTHERN KARNATAKA

Mahadevu P., Shobha D., Mallikarjuna N., Jadesha G., Ravindrababau B.T., Shivakumar B.S. and Swapna G.
AICRP on Maize, Zonal Agricultural Research Station, Mandya

Maize is an important multipurpose crop grown for food, feed, fodder, culinary and industrial purpose in fulfilling food and nutritional needs of both human and livestock. Recently developed QPM hybrids play an important role in terms of fulfilling the micronutrients through biofortified maize and concentrated feeds. We evaluated different QPM hybrids during Kharif season at Zonal Agricultural Research Station, V.C.Farm, Mandya during 2015-16 to 2018-19. Among the HQPM hybrids evaluated, HQPM-7 recorded highest mean grain yield of 9034 kg/ha as compared to other HQPM hybrids and normal grain hybrids HEMA (8533 kg/ha) and MAH-14-5 (8396 kg/ha). Similarly, the hybrid HQPM 7 also recorded higher grain yield of 9595 kg/ha as compared to other hybrids during Rabi 2017-18 at Mandya. These hybrids are found promising as a source of nutrient enriched maize based food and feed for achieving nutritional security for both human and livestock in the state.

I-49 COMBINING ABILITY ANALYSIS USING DIALLEL MATING DESIGN IN INBRED LINES OF MAIZE (*ZEA MAYS* L.)

Thakur D.K., Alam M.I. and Sinha S.K.
Section of Genetics and Plant Breeding
Indira Gandhi Krishi Vishwavidyalaya, Raj Mohini Devi Collage of Agriculture and Research Station, Ambikapur

The experiment entitled "Combining ability analysis using diallel mating design in inbred lines of maize (*Zea mays* L.)" was conducted at research cum instructional farm Ajirma, IGKV, RMD CARS, Ambikapur (C.G.) during *Rabi* 2016-17. The experiment was conducted in Randomized Complete Block Design (RCBD) involving (ten inbred lines, forty five crosses and five checks of maize with three replications. Analysis of variance showed that mean squares were highly significant for traits such as grain yield, 100 grain weight, days to 50% tasseling and silking, plant and ear height, ear length, ear girth, cobs/plot etc. High heritability coupled with high genetic advance was recorded for the traits plant height and ear height that depict the existence of additive gene effects. The analysis of variance for combining ability revealed that mean squares were significant for almost all the characters. Variance due to sca was greater than gca variance for the traits viz., plant height, ear height, number of kernels row/cob, number of kernels/row, ear length, cob yield and grain yield, which indicated the preponderance of non-additive gene effects in the genetic expression of these traits. The parents/inbred lines DMR 11 R 0144, Z 491-17 and IAMI-85 were found good general combiner. Experimental hybrids obtained with high specific combining ability (SCA) effect were DMR 11 R 0144/Z 491-17, Z 491-17/ IAMI – 85, IAMI-9/ IAMI – 85, IAMI-1/ Z 485-4, IAMI-1/Z 491-3 , IAMI-1/Z 491-17, CAL 1454/Z 485-4. Hybrids Z 491-17/ IAMI- 85, DMR 11 R 0144 / Z 491-17 and IAMI-9/ IAMI- 85 have shown 27.77%, 25.62% and 24.20% standard heterosis respectively against best check in NK-30 in trial.

I-50 LINE X TESTER MODEL FOR EVALUATING THE COMBINING ABILITY OF SOME NEW WHITE MAIZE INBRED LINES

Yadav N.K., Thakur D.K. and Sinha S.K.
Section of Genetics and Plant Breeding
Indira Gandhi Krishi Vishwavidyalaya, Raj Mohini Devi Collage of Agriculture and Research Station, Ambikapur

An experiment entitled ''Line x Tester Model for Evaluating the Combining Ability of Some New White Maize Inbred Lines'' was carried out at the Research cum Instructional farm, Ajirma, RMD CARS, Ambikapur, during *rabi* 2018-19 in Randomized Block Design, involving thirty-two crosses derived from eight lines and four testers. Analysis of variance showed that mean sum of squares was highly significant for all the characters. This means the genotypes differ significantly for different traits and there is no or very less environmental influence on the expression of traits. A relatively higher estimate of GCV was obtained for ear height, plant height, grain yield and no. of kernels/row. High heritability coupled with high genetic advance was recorded for the traits ear height, no of kernels/row, grain yield, ear length and test weight depicts the presence of additive gene effects. Results of combining ability revealed that the lines IAMI-14, IAMI-31 and IAMI-16 were found good general combiner for grain yield and most of the traits. The tester CML-540 and CML-545 were identified as a good general combiner for grain yield. The crosses IAMI-31/ CML-540, IAMI-14/CML-540, IAMI-03/CML-545 and IAMI-16/CML-545 were registered as a desirable specific combiner for grain yield and other important traits. Standard heterosis over Shaktiman-2 was found significant for crosses IAMI-31/CML-540 (48.16%), IAMI-14/CML-540 (40.44%), IAMI-03/CML-545 (33.08%) and IAMI-16/CML-545 (30.75 %).

I-51 INTROGRESSION OF *CRTRB1* THROUGH MARKER ASSISTED BACKCROSS BREEDING (MABB)

Yadav H.K.[1], Gangoliya S.K.[2], Yathish K.R.[3], Kumar A.[1], Preeti[1], Goshal T.[1], Srivastava S.[1], Kapoor U.[1], Kumar S.[1], Kumar R.[5], Singh S.B.[4], Sekhar J.C.[3], Das A.K.[5], Neelam S.[3], Yadav O.P.[6], Mahajan V.[7], Chikkappa G. Karjagi and Rakshit S.[5]

[1]Delhi Unit Office, ICAR-Indian Institute of Maize Research, New Delhi
[2]Maharana Pratap Government Post Graduate College, Gadarwara
[3]Winter Nursery Centre, ICAR-Indian Institute of Maize Research, Hyderabad
[4]Regional Maize Research and Seed Production Centre, ICAR-Indian Institute of Maize Research, Begusarai
[5]ICAR-Indian Institute of Maize Research, Ludhiana
[6]ICAR-Central Arid Zone Research Institute, Jodhpur
[7]ICAR-National Bureau of Plant Genetic Resources, New Delhi
chikkappagk@gmail.com

Maize (*Zea mays* L.) is grown on nearly 190 million ha in about 165 countries with total production yielding approximately 39% of total grain production. In India maize is third most important cereal crop after rice and wheat and accounts for around 10% of total food grain production. Maize contributes 25 to 35 per cent of total calories of the diets in several African, Asian and Latin American countries. Thus it is a valuable source of food and feed worldwide. Further enhancement of nutritional value through micronutrients like provitamin A in maize through biofortification could play an vital role in reducing the micronutrient malnutrition, the major challenge to ensure nutritional security in developing countries. Biofortification is the process by which the nutrient density of food crops is increased through conventional plant breedingand/or improved agronomic practices and/or modern biotechnology without sacrificing any characteristic that is preferred by consumers or most importantly to farmers. In the present study, gene encoding β-carotene hydroxylase 1 (*crtRB1*) alleles associated with higher β-carotene concentrations was introgressed into elite inbred line LM 17 and 19 using marker-assisted backcross breeding (MABB). The donor for *crtRB1* gene was CIMMYT-5 inbred line. For foreground selection *crtRB1* gene-based simple sequence repeat (SSR) markers were successfully used in foreground selection. Presently introgressed lines are in BC_2F_2 generation. In LM17 × CIMMYT-5 cross, out of 90 plants, 31 plants were homozygous, 42 plants were heterozygous while 17 plants were negative and in LM19 × CIMMYT-5 cross out of 167 plants, 54 plants were homozygous, 87 plants were heterozygous while 26 plants were negative. The plants carrying gene of interest, were screened with SSR markers and recovery of recurrent parent genome (RPG) in background selection ranged between 82.40 - 93.70% for the LM17 × CIMMYT-5 and 84.70-91.30% for LM19 × CIMMYT-5. The newly developed provitamin A near siogenic lines (NILs) developed in both the crosses are comparable with their recurrent parents for agronomic performance for different traits like days of anthesis, ear diameter, ear height, ear length, kernels per row and kernels rows, however the biochemical analysis is being carried-out.

I-52 HETEROTIC GROUPING OF INDIAN MAIZE INBRED LINES

Chikkappa G. Karjagi, Kumar R.[2], Singh S.B.[3], Yathish K.R.[4], Das A.K.[2], Neelam S.[4], Gangoliya S.S.[5], Kapoor U.[1], Yadav H.K.[1], Srivastava S.[1], Kumar A.[1] and Rakshit S.[2]

[1]Delhi Unit Office, ICAR-Indian Institute of Maize Research, New Delhi

[2]ICAR-Indian Institute of Maize Research, Ludhiana
[3]Regional Maize Research and Seed Production Centre, ICAR-Indian Institute of Maize Research, Begusarai
[4]Winter Nursery Centre, ICAR-Indian Institute of Maize Research, Hyderabad
[5]Maharana Pratap Government Post Graduate College, Gadarwara
chikkappagk@gmail.com

The concept of heterosis and its application in the form of hybrid technology for maize improvement has brought substantial increase in maize yield in most of major maize growing countries in the World like USA, China, European Union and Brazil. The maize hybrid development requires systematic characterization of the working germplasm with respect to heterotic affinity or behaviour of their germplasm to increase the efficiency of the breeding programme. In the present study, effort has been made to understand the heterotic pattern among the working germplasm. During 2017-18 a set of 54 inbred lines were crossed in line × tester design to two inbred testers namely LM13 and LM19 respectively to group the parental lines into different heterotic groups. The resulting test-crosses were evaluated in New Delhi under alpha design with two replications during 2018-19. The results indicated that the mean yield of testers were 4355 and 4781 kg/ha respectively and the highest testcross yield with LM13 and LM 19 were 7798 and 9269 respectively. The mean yields of lines ranged from 3283 and 4147 respectively. The GCA and SCA were estimated and the GCA of lines was in the range of -501 to 363. The specific combining ability of lines with LM13 was in the range of -1296 to 1093 whereas the SCA of lines with LM19 were in the range of -655 to 727. The 54 inbred lines were grouped into 26 and 28 lines with grouping affinity for LM13 and LM19 respectively.

I-53 INTROGRESSION OF LOW PHYTIC ACID TRAIT IN SELECTED INBRED LINES OF MAIZE

Kumar A.[1], Gangoliya S.S.[2], Yathish K.R.[3], Yadav H.K.[1], Preeti[1], Goshal T.[1], Srivastava S.[1], Kapoor U.[1], Kumar S.[1], Kumar R.[5], Singh S.B.[4], Sekhar J.C.[3], Das A.K.[5], Neelam S.[3], Yadav O.P.[6], Mahajan V.[7], Chikkappa G. Karjagi and Rakshit S.[5]
[1]Delhi Unit Office, ICAR-Indian Institute of Maize Research, New Delhi
[2]Maharana Pratap Government Post Graduate College, Gadarwara
[3]Winter Nursery Centre, ICAR-Indian Institute of Maize Research, Hyderabad,
[4]Regional Maize Research and Seed Production Centre, ICAR-Indian Institute of Maize Research, Begusarai
[5]ICAR-Indian Institute of Maize Research, Ludhiana
[6]ICAR-Central Arid Zone Research Institute, Jodhpur
[7]ICAR-National Bureau of Plant Genetic Resources, New Delhi
chikkappagk@gmail.com

Phytic acid (PA) is one of the important anti-nutritional factors which affect the bioavailability of micronutrients like iron, zinc. Maize being one of the important food and feed crop requires serious attentions to reduce its PA; majority of total phosphorous is stored in this form which makes it unavailable to monogastric animals. The phosphorus thus stored in the form of PA phosphate contributes to water pollution because it is excreted as such. PA being strong chelating agent also forms phytate salts with cation mineral elements like iron, zinc, calcium etc., thus affects the

bioavailability of micronutrient mineral elements. Thus causes micronutrient mineral deficiency in humans and phosphorous deficiency in animals. In the present study efforts have been made to introgress gene (*lpa2*) determining low-PA has been transferred from low-phytate mutant line *lpa2* into an elite inbreds LM14 and LM17 through marker-assisted backcross breeding (MABB). The BC_2F_2 near isogenic lines (NILs) have been developed through introgression of *lpa2* gene. Out of 118 BC_2F_2 plants of LM 17 × LPA2 family, 26 were homozygous positive for *lpa2* gene and 65 were heterozygous; the remaining plant were negative (27 plants). Similarly, in LM 19 × LPA2 cross, out of 127 BC_2F_2 plants 24 were homozygous for *lpa2*and 70 plants were heterozygous. The remaining plants were (33) were negative for the *lpa2* gene. The molecular marker, umc2230 was used as linked marker to select *lpa2* gene. Whereas the sequence tagged molecular markers (STMS), were chosen to select segregants with highest genome recovery. The recurrent parent genome (RPG) varies between 79-89 and 82-93 per cent in BC_2F_2 individuals derived from LM 17 × LPA2 and LM 19 × LPA2 respectively. The agronomic performance of selected NILs of BC_2F_3 and the respective recurrent parents has shown that the NILs are comparable with respective recurrent parents for days to flowering and almost all the yield component traits like number of ear length, ear girth, kernel rows, kernels per row, test weight etc. and also biochemical analysis for low-PA is underway. The NILs developed would be used to re-constitute the original hybrids.

I-54 CONVERSION OF NORMAL INBRED LINES INTO QUALITY PROTEIN MAIZE THROUGH MARKER ASSISTED SELECTION

Srivastava S.[1], Gangoliya S.S.[2], Yathish K.R.[3], Kumar A.[1], Preeti[1], Goshal T.[1], Yadav H.K.[1], Kapoor U.[1], Kumar S.[1], Kumar R.[5], Singh S.B.[4], Sekhar J.C.[3], Das A.K.[5], Neelam N.[3], Yadav O.P.[6], Mahajan V.[7], Chikkappa G. Karjagi and Rakshit S.[5]

[1]Delhi Unit Office, ICAR-Indian Institute of Maize Research, New Delhi
[2]Maharana Pratap Government Post Graduate College, Gadarwara
[3]Winter Nursery Centre, ICAR-Indian Institute of Maize Research, Hyderabad
[4]Regional Maize Research and Seed Production Centre, ICAR-Indian Institute of Maize Research, Begusarai
[5]ICAR-Indian Institute of Maize Research, Ludhiana
[6]ICAR-Central Arid Zone Research Institute, Jodhpur
[7]ICAR-National Bureau of Plant Genetic Resources, New Delhi
chikkappagk@gmail.com

Protein malnutrition is one of the challenges to ensure nutritional security of the global poor masses especially in rural population of the developing world. Cereals are deficient in some of essential amino acids like lysine and tryptophan. The deficiency leads to one of the protein deficiency disorder like kwashiorkor. Therefore the challenge is to deliver nutritious, safe and affordable food to reduce the impact of nutritional deficiency. Quality protein maize (QPM), contain double the amount of lysine and tryptophan as compared to normal maize is one of the intervention could play vital role to reduce amino acid deficiency. In this context, several efforts have been made to enhance the lysine and tryptophan levels through marker assisted introgression of *o2* gene into elite inbred lies of maize. In the present study, *opaque2* gene along with phenotypic selection for kernel modification was incorporated using marker assisted backcross breeding (MABB) program into normal inbred line *i.e.*

LM19. This is the parental line of popular single cross hybrids PMH6 in India. HKI 163 was the donor for *opaque2* allele. *opaque2* gene-based simple sequence repeat (SSR) markers were successfully used for introgression of *opaque2* allele. BC_2F_2 population derived from marker identified BC_2F_1 individuals were subjected to foreground selection. 86 BC_2F_2 plants derived from LM19 × HKI 163 cross were screened for *o2* gene linked molecular marker. The result showed that 50 plants were heterozygous, 18 plants were homozygous while 15 plants were negative for *o2* allele. The *o2* carrying homozygous plants were subjected to background selection using sequence tagged microsatellites (STMS) to accelerate the recovery of recurrent parent genome (RPG). The background selection has revealed that the RPG varied from 79-87 % in BC_2F_2 generation derived from LM19 × HKI 163 cross. The newly developed near isogenic lines (NILs) from the hard endosperm kernels were evaluated for desirable agronomic and biochemical traits in replicated trials and the best lines were chosen to represent the QPM version of LM19. The agronomic performance of the selected BC_2F_2 population for LM19 × HKI 163 inbreds showed comparable performance with LM17 in days of anthesis, days of silking and yield and yield component traits.

I-55 ESTIMATION OF HETEROSIS AND GENE ACTION FOR YIELD AND YIELD CONTRIBUTING TRAITS IN MAIZE (*ZEA MAYS* L.)

Tripathi A.[1], Choudhary J.R.[2] and Verma S.S.[3]
[1,3]Department of Genetics and Plant Breeding, G. B. Pant University of Agriculture and Technology, Pantnagar
[2]ICAR- Indian Agricultural Research Institute, New Delhi

The experiment was undertaken with ten maize inbred lines during *Rabi,* 2014 at N. E. Borlaug Crop Research Centre, Pantnagr. The present investigation was carried out with half diallel mating design involving ten parents under two different plant densities (high plant density and optimum plant density). Experimental material consisted of 10 parents, their 45 F1s and two checks, PSM1 and Vivek 43 were evaluated under RBD with three replications. The analysis of variance for combining ability over two different plant density environments (OPD and HPD) indicated that mean sum of squares due to GCA was significant for all the characters in OPD and HPD environments. However, the mean sum squares due to SCA was found significant for all the characters in both the environments. The GCA effects of parents in OPD, P1 for days to 50% tasselling, days to 50 % silking, ear height and in HPD P2 and P8 to be best general combiner for five traits as P2 for days to 50% tasselling, days to 50% silking, ear diameter, 100 kernel weight, grain yield and P8 for ear diameter, no of kernel rows per ear, grain yield. The promising cross combination for grain yield P1 X P10. For grain yield some promising crosses showing superiority over both mid parent and better parent. Crosses, P1 X P10, P4 X P9, P4 X P10, P5 X P7, P5 X P6, P2 X P9, P3 X P6, P3 X P8,, P4 X P10 showed high estimates of heterosis for grain yield.

I-56 DEVELOPMENT OF BABY CORN HYBRIDS USING CMS SOURCE

Garg T., Singh G., Sandhu S.K., Sharma S. and Chawla J.S.
Punjab Agricultural University, Ludhiana

Baby corn means harvesting of maize cobs within 2-3 days of silk emergence before pollination. But the major constrain in baby corn is to maintain the quality of the baby corn. To ensure the quality of baby corn detasseling is needed to prevent pollination. In order to maintain baby corn quality and reduce cost of cultivation, *cytoplasmic male sterility (cms)* based baby corn hybrids are required. At PAU, conversion programme of elite inbred lines has been initiated. Cytoplasmic *male sterile* line in the background of LM 15 is used for production of *baby corn* hybrids. In *kharif* 2018, in a trial 11 new hybrids along with 4 checks were tested. Out of the 11 hybrids, 5 hybrids were completely male sterile, 5 hybrids were completely male fertile whereas, one hybrid showed partial sterility. This indicted prevalence of restorer alleles in the inbred lines which were used to develop baby corn hybrid combinations. Out of 11 male sterile hybrid JH 32434 yielded 803 kg /acre as compared to male sterile check hybrids G 5414 and G 5417 which yielded 844 kg/acre and 825 kg/acre, respectively. But in hybrid JH 32434 baby corn picking started 4 days earlier as compared to check hybrids. Baby corn of hybrid JH 32434 is superior in terms of appearance as it has pale yellow in colour, as compared to cremish checks. The sugar content in hybrid JH 32434 is more as compare to check G 5414 and comparable with G 5417.

I-57 COMBINING ABILITY ANALYSIS USING QUALITY PROTEIN MAIZE INBREDS UNDER TEMPERATE CONDITIONS

Dar Z.A.[1], Lone A.A.[1], Naseer S.[1], Rasool F.[1], Dar S.A.[1], Habib M.[1], Khuroo N.S.[1], Ali G.[1], Abidi I.[1], Kumar R.[2], Ahangar M.A.[1], Bashir S.[1], Nissa S.[1], Rashid Z.[1] and Hakeem S.A.[1]

[1]AICRP on Maize, Srinagar

[2]ICAR-Indian Instituite of Maize Research, Ludhiana

The study was undertaken to estimate combining ability effects in quality protein maize (QPM) inbreds for yield and yield attributing traits in a line × tester programme comprising twenty-four hybrids produced by crossing eight QPM lines with three testers. Eight inbred lines (KDQPM-13, KDQPM-14, KDQPM-20, KDQPM-21, KDQPM-49, KDQPM-50, KDQPM-58 and KDQPM-60) were crossed with three testers (VQL1, VQL2 and VQL17) to produce twenty four F_1 hybrids during *Kharif*2016. Twenty four F_1 crosses were evaluated in a randomized complete block design with two replications during *Kharif*2017 and 2018 at Dryland (Karewa) Agricultural Research Station. Significant genetic differences were observed for mean squares of treatments for all traits under study. QPM line KDQPM-60 was identified as a good general combiner for grain yield plant^{-1} followed by KDQPM-21 and KDQPM-50. Also, KDQPM-60 was accompanied with significant and desirable GCA effects for days to 50 per cent tasseling, days to 50 per cent silking, number of kernels row^{-1}, 100 grain weightand protein content and hence can be selected for the development of QPM hybrids. Among the crosses, KDQPM-50 × VQL-1, KDQPM-60 × VQL-17 and KDQPM-13 × VQL-17 exhibited highly significant and desirable SCA effects for grain yield plant^{-1}. Therefore, these crosses may be utilized for developing high yielding QPM hybrids.

I-58 GENETIC VARIABILITY FOR ROOT ARCHITECTURAL TRAITS IN MAIZE (*ZEA MAYS* L.) INBRED LINES UNDER STRESS AND NON-STRESS CONDITIONS

Islam N.U.[1], Ali G.[2], Dar Z.A.[3], Rafiq S.[4] and Bhat A.[5]
[1]Division of Genetics and Plant Breeding, FoA, Wadura, Sopore, SKUAST-Kashmir
[2]Division of Genetics and Plant Breeding, Shalimar, SKUAST-Kashmir
[3]Dryland Agriculture Research Station, Budgam, SKUAST-Kashmir
[4]Division of Entomology, SKUAST Jammu
[5]Division of Entomology, FoA, Wadura, Sopore, SKUAST Kashmir

A well-developed root system as a constitutive trait is favourable in many environments. It enables the plant to make better use of water and minerals and is an important component of drought tolerance at different growth stages. Genetic variability studies in maize for root architecture are limited due to the highly heterogeneous root architecture within and among different cultivars as a response to a complex soil matrix. There are only few reports on the evaluation of genetic variability in maize roots architecture and their role in nutrient and water uptake efficiency. Constitutive differences in root traits like rooting depth play a major role in drought resistance of crops. However, a better understanding of root functional traits and how traits are related to whole plant strategies to increase crop productivity under different drought conditions is needed. The aims of this study were to examine the extent of variability in root architectural traits under drought and irrigated conditions and to evaluate their correspondence to drought tolerance. The present study was conducted in the greenhouse facility at the Division of Genetics and Plant Breeding, Faculty of Agriculture, Wadura, SKUAST-K. In the present study thirty maize inbreds were evaluated for various root and shoot traits under drought and irrigated conditions. The inferences from this study revealed that water stress throughout maize development significantly affected maize growth processes resulting in a sharp decrease in root depth, root biomass, root volume, shoot height and shoot biomass. However there was increase in root-shoot biomass ratio under stressed conditions. The highest percentage decrease under drought was observed for shoot biomass (113.18) followed by root volume (62.60) and root biomass (45.15) while as lowest percent decrease was recorded in root depth (35.64). The trait root - shoot biomass ratio had increased value under drought 247.36. Our experimental results suggest that the root parameters like root depth and root biomass, root- shoot biomass ratio are related and are implicated with drought tolerance and can be used as selection criterion for drought tolerance in maize.

I-59 IDENTIFICATION OF MAIZE INBRED LINES UNDER DEFICIT MOISTURE STRESS

Lenka D., Singh B.P. and Swain D.
Department of Plant Breeding and Genetics, College of Agriculture,
Odisha University of Agriculture and Technology, Bhubaneswar

Maize is mostly grown in kharif season, where it came across frequent deficit of water. The present investigation entitled "Identification of Maize inbred lines in deficit moisture condition" was undertaken using 35 maize inbred lines in Randomized block design (RBD) with 2 replications under deficit moisture condition during rabi 2018-19 by withholding irrigation at reproductive stage. There was a significant difference between genotypes of all the characters, which revealed wide range of variability. Genotypes UMARKOTE-3, CML-411, CML-122, CML-40, CML-27, CML-336, CML-191, CLO-2450, CAL-1415 were having significantly superior yield. High

heritability & high genetic advance were found for grain yield/ha, grain yield/plant, plant height, ear height, shelling percentage, cob length and total grain/plant revealed additive gene action. Correlation studies revealed that, grain yield/ha exhibited highly significant positive association with cob diameter, kernels, rows/cob, cob length, 100 grain weight, plant height and ear height. Similarly for physiological character, it is found that grain yield/ha exhibited highly significant positive association with chlorophyll content, chlorophyll stability index, cell membrane stability index and relative water content, but significantly negative association with leaf senescence. Path analysis revealed that the maximum positive direct effect on grain yield/ha was exhibited by days to 50% silking and cob length. Whereas plant height and kernel rows per cob recorded low and negative direct effect on grain yield/ha respectively. Similarly for physiological characters, the maximum positive direct effect on grain yield/ha was exhibited by relative water content, chlorophyll stability index, SPAD, but negative direct effect with leaf senescence and rolling. D^2 analysis was carried out for 16 characters, which partition the 35 genotypes into 6 clusters. Cluster-I and cluster-II each retain highest number of inbreds (13 inbreds). Cluster-VI is monogenotypic cluster containing only one inbred. Maximum genetic diversity that is highest inter cluster distance(highest D^2 value) was observed between cluster-I and cluster-IV indicating the inbreds included under these cluster are more divergent than other which is desirable for any plant breeding programme.

I-60 MARKER ASSISTED INTROGRESSIONS OF *O2* AND *CRTRB1* GENES FROM APQH-9 INTO LOCAL WHITE CULTIVAR

Kumar S. and Kumar R.
Department of Genetics and Plant Breeding, Ch. Charan Singh University, Meerut
sushilccsu999@gmail.com

Maize constitutes about 9% of the total volume of cereals produced and is the third most important crop after rice and wheat. Although, normal white maize is a good source of basic dietary requirement for human consumption, but it lacks the two essential amino acids tryptophan, lysine and beta-carotene. In developing countries, maize based diet causing stunted growth and protein malnutrition in children. Genes *opaque2* (*o2*) and *crtRB1* regulates the amount of lysine, tryptophan and beta - carotene, respectively. The present study was conducted in the Department of Genetics and Plant Breeding, Chaudhary Charan Singh University, Meerut, U.P. for stacking the genes *o2* and *crtRB1* in a traditional maize cultivar, Local White, using molecular markers. Local White maize cultivar (deficient for lysine, tryptophan and beta-carotene) was crossed with a maize hybrid APQH-9 in kharif season, 2017. APQH-9 is recently released from IARI, New Delhi, having genes for opaque 2 and beta-carotene. SSR marker *UMC 1066* and *crtRB1* marker were used for foreground selection of *opaque-2* gene and β-carotene, respectively. Heterozygous F_1 plants for *UMC 1066* and *crtRB1* markers were confirmed and selected. Selected F1 plants were backcrossed with recurrent parent Local White to generate BC_1F_1 plants in kharif season, 2018. BC_1F_1 population was planted in kharif, 2019 and DNA from the plants at seedling stage was isolated for foreground selection. Foreground selection was carried to select the plants having both genes either in homozygous or heterozygous condition.The present investigation demonstrated successful introgression of the desired *opaque 2* and *crtRB1* alleles from APQH 9 to local white using marker assisted backcross breeding in the BC_1F_1 generation.This population was further backcrossed with recurrent parent to generate BC_2F_1 seeds. After sufficient generations of backcrossing, foreground and background selections followed by selfing a new version of Local White cultivar may be developed which may be further evaluated for yield and may be proposed for release as a new cultivar.

I-61 RECONSTITUTION OF BIOFORTIFIED MAIZE HYBRIDS POSSESSING FAVOURABLE ALLELES OF *B-CAROTENE HYDROXYLASE, LYCOPENE*-E-*CYCLASE* AND *OPAQUE2* FOR COMBINING HIGH PROTEIN, MINERALS, TRYPTOPHAN AND PROA IN MAIZE

Sharma S.[1], Singh J.[1], Kaur H.[2], Vikal Y.[1], Gill G.K.[2], Kumar A.[3], Sharma S.[2] and Hossain F.[4]
[1]School of Agricultural Biotechnology, [2]Department of Plant Breeding and Genetics, Punjab Agricultural University, Ludhiana
[3]Regional Research Station, Gurdaspur, Punjab Agricultural University, Ludhiana
[4]ICAR-Indian Agricultural Research Institute, New Delhi
shikhapanjolia@gmail.com

Traditional yellow maize though contain high kernel carotenoids, but the concentration of provitamin A is quite low (<2µg/g) as compared to recommended level (15µg/g). Enriching corn with vitamin A, will serve and assure the human population feeding on maize with enriched nutritive factor providing solution for blindness and major diseases caused by vitamin A. Here, we report the development of nutritionally enriched PMH1 and Buland hybrids, using marker assisted introgression of *β-carotene hydroxylase, lycopene-ε-cyclase* and *opaque2* favourable alleles in elite inbred lines viz. QLM11, QLM12, QLM13 and QLM14. These inbreds are parental lines of high yielding commercial maize hybrids in North India viz. Buland and PMH1 respectively. For this purpose, F_1, BC_1F_1, BC_2F_1, $BC_2F_2$and BC_2F_3 plants were developed using β-carotene rich CIMMYT (HP-467-15) line as donar parent and QLM inbred lines as the recurrent parents. The QLM inbred lines was crossed to HP-467-15 to produce $F_{1s}$and their testing for heterozygosity was done using gene-specific markers. Heterozygous plants with high recovery of the recurrent parent genome obtained functioned as males were then backcrossed to recurrent female parent twice to produce BC_1F_1 and BC_2F_1 in 2015 & 2016 respectively and were subjected to foreground, background and phenotypic selection. Furthermore, the selected heterozygous BC_2F_1 plants from both crosses were selfed to obtain BC_2F_2 plants, which were then selected for the target genes and selfed to generate the BC_2F_3, BC_2F_4 and BC_2F_5 populations. The improved lines have good agronomic performance and possessed high protein (4.40-9.76), tryptophan (0.60-3.84)and β-carotene (9.21-12.44 µg/g) content. The reconstituted hybrids showed an average of 4.5-fold increase in proA with a range of 9.25–12.88µg/g, compared to original hybrids (2.14–2.48µg/g). Similarly, the agronomic traits viz. plant architecture, ear and grain characteristics of improved versions of both inbreds and hybrids were observed when evaluated with their respective original versions. Mean protein (11.76%) and tryptophan (4.74%) of the improved hybrids were *at par* with the original versions (protein: 6.43%, tryptophan: 1.89%). Improved hybrids also possessed similar grain yield potential with their original versions evaluated at two locations. These biofortified high yielding maize hybrids, rich in proA, tryptophan and percent protein possess great potential to simultaneously alleviate Vitamin A deficiency and protein-energy malnutrition across the world.

I-62 PRODUCTION POTENTIAL AND ECONOMIC FEASIBILITY OF MAIZE AND PULSE INTERCROPPING IN DIFFERENT ROW RATIOS UNDER RAINFED CONDITIONS OF NORTH- EAST INDIA

Singh S.D., Nongmaithem N., Konsam J. and Senjam P.
Directorate of Research, Central Agricultural University, Imphal
sanj_day@yahoo.com

A field experiment was conducted during *kharif* season of 2016-17 at upland research farm of ICAR, Mizoram centre, Kolasib. The experiment was undertaken to evaluate the effect of maize and pulse intercropping under different row ratios on its yields, yield attributing characters, intercropping efficiencies and monetary return. The results of the experiment showed the yield and yield attributing parameters of the sole crops were higher than the yields in intercropping system. There was a trend of decreasing maize yield with increasing row ratio in intercropping treatments, however, the intercrops (soyabean and green gram) yield were increased with increase of row ratios. Maize intercropping with green gram at 1:2 ratios produced the maximum land equivalent ratio (1.471) and land equivalent coefficient (0.536) whereas maize+soyabean in 1:2 ratio produced the highest area time equivalent ratio (1.270). Among the competition indices, relative crowding coefficient value (11.672) was maximum under maize+green gram in 1:1 ratio. There was positive aggressivity of maize and negative aggressivity in soyabean and green gram. In terms of monetary return parameters such as maize equivalent yield, system productivity, production efficiency, net return and B:C ratio were attributed to maize+soyabean at 1:2 ratios.

I-63 EFFECT OF DETOPPING ON YIELD OF MAIZE CROP

Rajanikanth E., Manjulatha G., Sravani D., Usharani G. and Vijayabhaskar A.
Agricultural Research Station,
Professor Jaya Shankar Telangana State Agricultural University, Karimnagar

Now days fodder is the main constraint in particularly during *rabi* season. In maize growing areas, the de-topped Maize is one of the alternative sources of fodder, which may be used as green fodder. Hence to find out the effect of detopping on Maize yield this experiment was planned. A field experiment was conducted at Agricultural Research Station, Karimnagar for two years during *Rabi* 2013-14 & 2014-15, to find out the effect of de-topping on maize yield in red sandy loam soils. The initial soil status indicated of high available N, P, K (613.9, 62.8, 436 kg/ha respectively). The experiment was carried out in Randomized block design in two sub experiments. First sub-experiment conducted with 7 treatments (Stages of De-topping *i.e* T1 - 14 Days after tasseling (DAT), T2 - 19 DAT, T3 - 24 DAT, T4 - 29 DAT, T5 - 34 DA7, T6 - 40 DAT & Control -Without De-topping) and with 6 treatments in second sub-experiment (Length of De-topping *i.e* T1 - The fifth node above the cob, T2 - The fourth node above the cob, T3 - The third node above the cob, T4 - The second node above the cob, T5- One node above the cob & T6- Control (Without De-topping). Significantly higher grain yield and yield attributes were recorded with control (no detopping) and it was on par with detopping (by leaving five leaves above the cob) at

40 days after tasseling in addition green fodder yield of 1.96 t/ha is obtained. Detopping by leaving two, three and four leaves above the cob placement resulted in 22, 18 & 17% yield loss respectively than compared to the control.

I-64 OPTIMIZATION OF DOUBLED HAPLOID PRODUCTION USING TROPICAL ADOPTED INDUCER LINES IN MAIZE (*ZEA MAYS* L.) UNDER NORTHERN HIMALAYAN CONDITIONS

Kumar S.[2], Guleria S.K.[1], Chandel U.[3] and Devlash R.[1]
[1] Hill Agricultural Research and Extension Centre, Bajaura, Kullu
[2]Department of Genetics and Plant Breeding, Chaudhary Sarwan Kumar Himachal Pradesh Krishi Vishva Vidyalaya
[3]Shivalik Agricultural Research and Extension Centre, Kangra
skg0612@rediffmail.com

Use of noble doubled haploid technology in maize (*Zea mays* .L) has offered numerous advantages such as maximum genetic variances, simplified logistic, reduced expenses and time for the development complete homozygous inbred lines. CIMMYT's Tropical Adopted Inducer line TAIL P_1 and hybrid TAIL P_1 x TAIL P_2 were used for generation of haploids during *kharif*, 2016 and 2017 at CSK HPKV, Hill Agricultural Research and Extension Center Bajaura. These lines used as male were crossed with source germplasm (Public and Private hybrids, heterotic pools and populations) to assess the haploid induction rate (HIR), the chromosome doubling rate (both silk and pollen shedding present on the plants in the field) of haploid seeds after treatment of different doses of colchicine of 0.04, 0.06 and 0.08 percent solutions for different duration of 8, 12and 15 hours. Data on total seed set, putative haploid seed, selfed seed set was recorded on each crossed cobs. The R1-nj anthocyanin marker system was found effective for haploid identification in all the hybrids, though hybrid with HQPM 1(source germplasm) showed no kernel pigmentation which may be due to the presence of inhibitor gene in the genotype. The results showed that haploid induction rate (HIR) was ranged from 0.88 to 13.61 per cent in *kharif,* 2016 and it was ranged from 1.34 to 12.50 per cent in *kharif*, 2017. On the basis of two years study HIR was recorded to be 5.27 per cent. For optimizing the dosage of colchicine treatment for doubling the chromosome, the highest plant survival rate (44.89 per cent) was recorded in 0.04 per cent colchicines treatment for 8 hours duration. Haploid seedling treated with 0.06 per cent for 8 hours and 0.04 per cent for 12 hours also gave good results for plant survivability of 38.17 and 42.13 per cent, respectively. Among these doses of colchicines only 0.04 percent for 12 hrs was observed as the best dosage having maximum doubled haploid formation is 14.39 per cent. More than fifty DH lines developed showed good adaptation, have good morphology and high yield and most of them are highly uniform for different traits like plant height, cob placement, silk colour ,tassel size and anther colour etc which are being utilized in our hybrid breeding programme. In conclusion, CIMMYT inducer lines have good adaptation for generation of doubled haploid inbred lines in Northern Himalayan conditions.

I-65 GENETIC DIVERSITY OF QPM INBREDS USING MORPHOLOGICAL CHARACTERS

Kumar A, Chand P., Alam T., Pramanick B., Kumar V. and Kumar A.

Dr. Rajendra Prasd Central Agricultural Univerisyt, TCA, Dholi

A study was undertaken to characterize and evaluate eighteen locally adapted inbred lines of maize for various morphological characters to estimate the extent of genetic diversity among these maize inbred lines using morphological characterization. The present investigation field research work was undertaken during *kharif* 2018 in Randomized Block Design (RBD) with 3 replication having plot size of 1.5 x 4.0 = 6 m^2 at TCA Dholi farm, R.P.C.A.U,Pusa, Samastipur, Bihar.The characters studied were Days to 75% tasseling, Days to 75% silking, Daysto 75% brown husk, Plant height(cm), Ear height(cm), Ear length(cm), Ear girth (cm),Tassel length (cm), Number of kernel rows per ear, Number of kernels per row and Grain yield (Kg/ha). The morphological characterization include biometrical analysis of genetic divergence using D^2 statistic by Tocher's method..Analysis of variance revealed highly significant differences among the inbred lines for all the parameters. All the 25 QPM inbred lines were grouped into 7 clusters using D2 statistics using Tochers method. The maximum intra cluster distance was observed in cluster IV and minimum intra cluster distance was observed in cluster III. The highest inter cluster distance was observed in between Cluster I and VI. Genotype from these clusters may be selected as parents for hybridization programme for developing new hybrid combinations. Among 299 combinations, ear length ranked 1st followed by grain yield, ear height, plant height, days to 75 % tasseling, tassel length, no. of kernels per row, ear girth, days to 75 % silking and No. of kernel rows per ear, The maximum cluster mean was observed in cluster III and minimum cluster mean was observed in cluster VI. Therefore, selection of parents from different clusters might be done for desired traits on the basis of higher cluster mean values, suggesting scope for Improvement in these characters.

I-66 COMBINING ABILITY AND HETEROSIS FOR GRAIN YIELD AND YIELD ATTRIBUTING TRAITS IN MAIZE THROUGH DIALLEL MATING DESIGN

Sarojini S.[2], Swain D.[1] and Mishra T.K.[2]
[1]AICRP on Maize, [2]Department of Plant Breeding and Genetics
Odisha University of Agriculture and Technology, Bhubaneswar

Combining ability and heterosis study provides necessary information for identification of promising cross combinations which are likely to produce higher heterotic effect for development of commercial hybrids. In the present experiment, 15 F_1s produced from 6 x 6 diallel crosses without reciprocals (Griffing's Method-II, Model-2) were evaluated along with six inbreds and four standard checks in randomized block design with three replications during *Rabi* season at AICRP on Maize, OUAT, Odisha. ANOVA for combining ability revealed significance of mean squares due to GCA and SCA variances for grain yield and ten yield attributing characters indicating both additive and non-additive gene action in expression of these traits. However, higher magnitude of SCA variance in comparison to GCA variance indicated predominance of non-additive gene action for these traits. CML 451 was the best general combiner for grain yield/ plant followed by CAL 1473. CML 451 was also best general combiner for number of kernel rows/ cob and good general combiner for number of kernels/ row and shelling %. CAL 1473 was also best general combiner for days to 50% pollen shedding, days to 50% silking and number of kernels/ row. SNL 14-28-28 was found to be best general combiner for ear length. Nine crosses out

of 15 crosses exhibited significant and positive SCA effects. The range of heterobeltiosis for grain yield/ plant ranged from 0.65% to 34.13% and 12 crosses showed significant positive heterobeltiosis for this trait, while the standard heterosis over best check hybrid, P 3522 ranged from -12.2% to 14.5% and five crosses exhibited standard heterosis of around 10% or more. Five crosses i.e., SNL 14-28-28 × CML 451, CAL 14-13-7 x CAL 1473, CAL 1473 x CML 451, CAL 14-13-7 × SNL 14-28-28 and SNL 14-28-28 × CAL 1473 were found to be the promising for exploiting hybrid vigour for grain yield on the basis of SCA effects, heterosis and *per se* performance. The performance of these crosses is to be revalidated further for their commercial use in future.

I-67 ANALYSIS OF DNA MOTIFS UPSTREAM OF *OPAQUE2* GENE IN MAIZE GENOME

Singh A.[1], Chikkappa G. Karjagi, Kaur S.[3], Gaganjeet[3], Chaudhary D.P.[1], Kumar R.[1], Naliath R.[1], Das A.K. and Rakshit S.[1]
[1]ICAR-Indian Institute of maize Research, Ludhiana
[2]Delhi Unit Office, ICAR-Indian Institute of Maize Research, New Delhi
[3]Punjab Agricultural University, Ludhiana
alla.singh@icar.gov.in

Gene expression is regulated amongst other factor, by the DNA elements present outside the Open Reading Frame that codes for protein. *Opaque2* (*o2*) gene codes for a transcription factor protein, responsible for determination of protein quality in maize. A mutant version of the locus leads to higher content of two essential amino acids, lysine and tryptophan. The agronomically improved version of *opaque* maize, referred to as Quality Protein Maize, has been used for alleviating malnourishment in national food programs of some countries. There is interest to convert elite, locally-adapted germplasm to QPM version by introgression of the *opauqe2* gene. The agronomic quality, including kernel hardness is restored by incorporation of modifier genes that act to bring a balance between amino acid content and grain quality. We have computationally analyzed the upstream region of *opaque2* gene and found that it contains two transcription factor binding sites. One site is present in the marker phi112, a dominant marker that differentiates *opaque* maize from normal maize. Another site is present downstream of the marker, but upstream of the start site of *O2* gene. The analysis provides insight to the molecular regulation of the *opaque* locus and implicates possible modifier proteins that act on the *opaque* locus, influencing the overall protein quality of maize.

I-68 PUBLIC PRIVATE PARTNERSHIP – A SYMBIOTIC APPROACH FOR MEETING SEED DEMAND OF PUBLIC BRED MAIZE HYBRIDS

Bhadru D., Anuradha G., Mallaiah B., Srilatha D. and Reddy M.L.
Maize Research Center, Rajendranagar, Hyderabad

With continuous efforts of Indian institute of Maize Research and State agricultural Universities, a total of 212 hybrids and 119 composites of maize have been released till date with a wide range of maturity to cater to the needs of farmers in different production ecologies of various states of India. The adoption of improved cultivars and production technology had a synergistic effect on crop productivity and provided encouraging results in farmers' fields. In spite of public sector having high yielding maize hybrids, there exists a large gap to spread on to larger areas in comparison to that of private bred maize hybrids. Still, 90% of the hybrids in the market is covered by the private sector hybrids. To increase the area under public bred maize hybrids and to meet the seed demand of the farmers, Professor Jaya Shankar Telangana Agricultural University (PJTSAU) has initiated memorandum of understanding (MoU) with private seed production companies and Farmers Co-operative Societies in the year 2010 for production and marketing of two maize single cross hybrids viz., DHM 117 and DHM 121 developed at the University with a royalty of 3.0 lakhs covered for a duration of four years. Supply of breeder seed is University's responsibility on payment basis. This decision was well taken by the seed companies and Govt. organizations and many of them came forward and entered into MoU with the University for Seed Production of above hybrids. So far 25 companies (16 for DHM 117 & 9 for DHM 121) have registered with the University since 2010. In addition to this Public Seeds Corporations viz., National Seed Corporation and State Seed Corporations of Telanganaandhra Pradesh, Rajasthan, Maharashtra, Gujarat and West Bengal are involved in production of DHM 117 and DHM 121 seed to meet the requirements of their respective states. Initially, Maize Research Centre (PJTSAU) had supplied 50q breeder seed of parental lines to the above organizations both public and private together. However, during last five years the supply reached to 300q of breeder seed of parental lines. The private companies under MOU along with State Seed Corporations of different states together produced certified seed of maize hybrids (DHM 117 and DHM 121) and this seed was sown in an area of one lakh hactares. With this initiative, it is expected that in future there is an ample scope for the public bred maize hybrids to spread in larger areas thereby enhancing farmers income as there also exists chances for their participation in seed production through farmers co-operatives.

I-69 DESIGNING PLANT ARCHITECTURE FOR HIGH DENSITY PLANTING IN MAIZE: A STEP TOWARDS PRODUCTIVITY ENHANCEMENT

Sarkar A., Sandhu S.K. and Kumar M.
Maize Section, Department of Plant Breeding and Genetics
Punjab Agricultural University, Ludhiana
aditi-pbg @pau.edu

Achieving sustainable food security with limited arable land is a major challenge in today's scenario of changing climate and increasing global population. Maize plays an increasingly vital role in global grain production. Maize, a C4 plant, has high yield potential and is predicted to become the number one cereal in the world by 2020. With the menace of paddy straw burning issues and hence environmental consequences coupled with depletion of underground water, maize crop has more strongly emerged as a candidate for crop diversification during kharif season in Punjab but the wide gap in potential and actual productivity of maize hinders the economic viability and consequently wider adoption by the farmers in Punjab state. High-density planting which envisages higher productivity by increased plant population per unit area has undergone a constant evolution over the years, with the purpose of enhancing the crop yield and has been documented as is one of the research interventions to break the maize productivity plateau. Earlier studies in this domain indicated that crowding stress reduced the ability of plants to use soil N

prominently during the post silking period. The increased incidence of lodging and biotic stresses has also been indicated. Recently, Punjab Agricultural University (PAU), Ludhiana has taken up designing plant architecture amenable to high density planting. It is expected that the high density apposite inbred lines would generate high density responsive hybrids. Understanding of the traits which makes the plant best suited to higher plant population is of critical importance for the improvement of maize productivity through high density planting. The identification of efficient inbred lines, with key variants which may facilitate to cope up crowding stress *viz.,* altered plant height, leaf angle and area, ear placement, ear and kernel traits and maturity patterns, has been carried out. A germplasm stock available at PAU comprising materials from inbred lines from CIMMYT, Mexico; NBPGR, New Delhi, local collections; WNC, Hyderabad and inbreds from different pools being maintained at PAU were sown in plot of 4 rows of 4m each at 60 x 20cm plant to plant and row to row spacing, respectively in *kharif*, 2019. About 50 lines were identified which harbored traits contributing towards HDP. Amongst selected lines, PML 1049, PML 387, JCY-45, PML-368 and JCY 31-1 possessed the maximum number of traits contributing towards suitability to HDP. These lines have been identified with narrow, erect to semi erect leaves with leaf angle ranging from 45^{o}-60^{o}, medium high ear placement, less number of branches in tassel and stay green plant habit. These inbred lines can be utilized in breeding program for development of hybrids tailored for high density planting thus, contributing towards productivity enhancement.

I-70 STUDIES ON HETEROSIS FOR GREEN EAR YIELD AND ITS COMPONENT TRAITS IN SWEET CORN HYBRIDS

Praveena V.M[1]., Talekar S.C[2]., Kachapur R.M[3] and Harlapur S.I[3]

[1]Department of Genetics and Plant Breeding, University of Agricultural Sciences, Dharwad

[2]AICRP on Rice, ARS, Mugad

[3]AICRP on Maize, MARS, Dharwad

Maize considered as queen of cereals, is cultivated in more than 150 countries, is the world's third most important crop after wheat and rice. Among the various speciality corns, sweet corn is differentiated from other maize types by the presence of genes which alters endosperm starch synthesis and results in the plant to be used as vegetable has a very huge market potential in national and global market. Heterosis of 42 single cross hybrids of sweet corn derived from 7×7 diallel mating were evaluated along with seven parents and three checks (Central Maize VL sweet corn 1, Madhuri and Misti) in Randomized block design in three replications with spacing of 60 × 20cm during Kharif 2019 at AICRP on Maize, MARS, Dharwad. The data was collected on traits *viz.,* days to 50% tasseling and silking, plant height(cm), ear height(cm), ear length(cm), ear girth(cm), number of kernel rows, number of kernels per row, green ear yield (t/ha), fresh ear yield without husk(t/ha), fodder weight (t/ha), total soluble solids (TSS %) and Turcicum leaf blight. The direction of heterosis was trait dependent and significant heterosis was observed for all characters studied except for days to 50% tasseling and silking. Almost all crosses showed highly significant and positive heterosis for ear length, ear girth, number of kernel rows and number of kernels per row which are associated with high yields. Significant and positive heterosis was observed in 29x26, 29x30 and 29x31 crosses over standard (Misti) and next best (CMVL SC 1) checks for green ear yield. Significant and positive mid parent and better parent heterosis was observed in 37 crosses for green ear yield. Thirteen crosses showed highly significant and positive mid parent, better parent and economic heterosis over two standard checks (CMVL SC 1 & Madhuri) for fresh ear yield without husk. Thirty crosses showed highly significant and positive mid parent, better parent and economic heterosis over one standard check (Madhuri) for green fodder weight. For TSS, three crosses 29×27, 29×31 and 31×29 exhibited significant and positive heterosis over mid parent, better parentand two standard checks (Central Maize VL Sweet Corn, Madhuri) indicating the scope for improvement in TSS. Though the cross 29×27 showed highest and positive TSS among all crosses, green ear yield was not significant and positive heterosis. Among all new crosses, two hybrids viz., 29×31 and 30×28 showed significant and positive heterosis for TSS, green ear yield, fresh ear weight without husk, green fodder weight and for other traits also indicating that these hybrids have the potential yielding ability which needs to be tested over locations for their stable performance.

I-71 BIOCHEMICAL CHARACTERISATION OF MAIZE FOR STARCH DIGESTIBLITY CHARACTERISTICS

Dhir A.[1], Das A.K.[2], Rakshit S.[2] and Chaudhary D.P.[2]
[1]Punjab Agricultural University, Ludhiana
[2]ICAR-Indian Institute of Maize Research, Ludhiana
chaudharydp@gmail.com

Maize, queen of cereals, is the most widely consumed cereal crop after wheat and rice. A maize kernel contains starch (75%) as the major component, which is composed of amylose (25-30%) and amylopectin (75-70%). Dietary starches vary greatly in digestibility. Resistant Starch (RS), a fraction that escapes the enzymatic hydrolysis, is positively correlated to amylose content which owing to lesser number of reducing ends, is more resistant to digestion, making RS more desirable for diabetics. This directs the present study, which aims at screening high amylose germplasm from eighty Quality Protein Maize lines which were analysed for starch, amylose and amylopectin content. The germplasm is broadly characterised into low (16-21%), medium (21-28%) and high amylose (more than 28%) lines. It was observed that 17 lines had low, 14 had high and rest had moderate amylose content. The screened high amylose lines were enzymatically analysed for RS, RDS and SDS content. The method deals with starch isolation using NaOH under cold conditions followed by addition of α-amylase and amyloglucosidase for starch hydrolyses. Further the aliquot of hydrolysates taken at 20, 120 and 180 minutes were estimated for glucose content using GOPOD reagent at 510 nm. The present study screens high amylose nutritionally superior lines from the Indian germplasm, which can be further modified to amylose extender lines so as to serve a potential substitute for fibrous constitutes in diet with an additional protection from the onset of bowel diseases.

I-72 ENABLING MARKET LINKAGE OF HIGH-PROTEIN MAIZE WITH FOOD INDUSTRY FOR DIVERSE APPLICATIONS

Kaur C., Sethi M., Kumar R., Singh A., Chaudhary D.P. and Rakshit S.
ICAR – Indian Institute of Maize Research, Ludhiana
chaudharydp@gmail.com

Protein is a commercial trait in food industry. Apart from its role in human nutrition, the presence of high protein content is beneficial for many fast moving consumer goods (FMCGs) like bread, flakes, etc. High protein also carries philanthropic advantage, as it is essential to prevent malnourishment in deprived parts of world and can well be accommodated into national food policy programs. Breeding efforts for more than over a century have resulted in a tremendous increase in maize protein in Illinois High Protein (IHP) lines, achieving more than 30% protein content in grain. It is imperative to utilize such germplasm for improvement of local germplasm and deploy maize for its utilization by food industry. In order to enable market linkage, inexpensive, easy and quick protocols are required to screen the maize grain to differentiate the bulk procurement and obtain the high protein amongst it. We have developed a protocol that provides a good estimate of protein content in maize germplasm and hence, can be used for market linkage of high-protein maize to food industry. The previous methods of rapid protein differentiation and the advantages of the present method are discussed.

I-73 STUDIES TOWARDS IMPROVING PROTEIN QUALITY ASSAY IN QPM

Kaur C.[1], Singh A., Kumar R.[2], Chaudhary D.P.[2] and Rakshit S.[2]
[1]Punjab Agricultural University, Ludhiana
[2]ICAR-Indian Institute of Maize Research, Ludhiana
chaudharydp@gmail.com

Quality protein maize (QPM) is a nutritionally superior commodity having the desired concentration of essential amino acids such as tryptophan and lysine. However, this nutritionally superior maize could not become popular in the absence of any remunerative price for this commodity. The similarity in kernel appearance between QPM and normal maize thus necessitates the development of a rapid assay method to assess the protein quality of QPM. The present study deals with optimization of defatting time, expedition of protein hydrolysis and total protein estimation that are the three major components of tryptophan estimation process. The results revealed that defatting for a period of 48 hours is sufficient for QPM and *opaque-2* in order to correctly estimate the tryptophan content. The proprietary formulation developed by IIMR is found to be quite efficient in carrying out complete protein hydrolysis at 120ºC in just 15 minutes. Further, it was concluded that Bradford method is positively correlated to Kjeldahl method (R^2= 0.81) and can efficiently be utilized for rapid estimation of protein concentration in maize. Thus, unlike enzymatic method which requires 2-3 days for defatting, 18 hours of incubation for protein hydrolysis and approximately 2-3 hours for total protein estimation, the present study is effectively useful to improve protein quality assay in maize.

Theme-II

Biotic and Abiotic Stress in Maize – Impact and Management

II-1 EFFECT OF BIO-PRODUCTS ON THE GROWTH OF *HELMINTHOSPORIUM MAYDIS* / *BIPOLARIS MAYDIS* BY DUAL CULTURE TECHNIQUE UNDER IN-VITRO CONDITION

Debnath S.[1], Kuilya J.[2] and Biswas S.[3]
[1, 2]Department of Plant pathology, Bidhan Chandra KrishiViswavidyalaya, West Bengal
[3]Department of Agronomy, Bidhan Chandra KrishiViswavidyalaya, West Bengal

Maize belongs to the family Poaceae, is the third most important cereal crop under irrigated and rainfed agricultural system in semi-arid and arid tropics and also known as queen of cereals. It is very much important in world's agriculture economy as source of food for man & feed for animal. The yield of this crop is challenged by a number of biotic stresses among which maydis leaf blight / southern corn leaf blight disease caused by *Helminthosporium maydis / Bipolaris maydis* is very much important specially in warm & humid maize growing areas. In India as well as in West Bengal this disease of maize is very much important. Proper management of this disease should be followed for minimizing the loss due to this disease attack. Cultural, chemical and biological control measures are important ways of disease management. Control of plant diseases by using biocontrol agents and natural / plant products is an eco-friendly & sustainable approach. Considering the hazardous effects of fungicides and chemicals, in this experiment for the purpose of management of MLB of maize three bio-control agents and three natural products were tested against *H. maydis* under in-vitro condition. Two plant extracts *Allium Sativum* (garlic), *Azadirachta indica* (neem), three bioagents *Trichoderma viride, Trichoderma harzianum* , *Pseudomonas fluorescence* and one natural product cow urine were tested against the growth of *Helminthosporium maydis* under in-vitro condition. Among the six treatments minimum radial growth (1.13cm) & maximum growth inhibition (82.8%) of *Bipolaris maydis* was found in case of application of *Trichoderma harzianum* followed by *Trichoderma viride* (radial growth – 1.30cm & growth inhibition 80.21%) with no significant difference among them. The growth inhibition of 35.61% was recorded in case of *Pseudomonas fluorescens* respectively. Better result was obtained when three bio-control agents were applied but among the natural products better result (radial growth 4.47cm & growth inhibition 31.96%) was obtained with application of garlic bulb extract (10%) followed by application of neem extract (radial growth 4.92cm & growth inhibition 25.11). Six bioproducts were evaluated under in-vitro condition against *Helminthosporium maydis*. The result revealed that, bulb extract of garlic (*Allium sativum*) at 10 per cent concentration completely inhibited mycelial growth of the fungus. Among the six treatments minimum radial growth (1.13cm) & maximum growth inhibition (82.8%) of *Bipolaris maydis* was found in case of application of *Trichoderma harzianum* followed by application of *Trichoderma viride* (radial growth – 1.30 cm & growth inhibition 80.21%)and they are statistically at par. Among the natural products better result (radial growth 4.47cm & growth inhibition 31.96%) was obtained when garlic bulb extract (10%) was applied.

II-2 EVALUATION OF DIFFERENT BIO-PESTICIDES AGAINST *CHILO PARTELLUS* INFESTING MAIZE

Chhangani G., Mahla M.K. and Vyas A.

Department of Entomology, Rajasthan College of Agriculture,
Maharana Pratap University of Agriculture and Technology, Udaipur
gaurangchhangani@gmail.com

The experiment to evaluate the efficacy of bio-pesticides against *C. Partellus* was conducted at Agronomy Farm, RCA, Udaipur during *Kharif*- 2018. The result revealed that Spinosad @ 1 ml/3 litre was found most effective bio-pesticide against stem borer with the minimum leaf injury rating (LIR) of 2.13. However, the application of Delfin WG @ 5 gm also proved effective in controlling stem borer with mean LIR 2.50. The data reveal that the stem borer infestation in terms of LIR ranged from 2.13 to 6.10 in different treatments. The highest LIR 6.10 was recorded in application of Bb-45 isolate of *Beauveria*, which was found least effective in controlling stem borer under artificial infestation.

II-3 GENETIC MAPPING FOR RED FLOUR BEETLE RESISTANCE IN MAIZE BACKCROSS INBRED LINE POPULATION

Joshi A., Adhikari S, Sahoo S. and Singh N.K.
Department of Genetics and Plant Breeding, College of Agriculture,
G. B. Pant University of Agriculture and Technology, Pantnagar

Red flour beetle *Tribolium castaneum* (Herbst) is a major secondary pest of maize products and is also known to damage the germ portion of whole maize kernels causing yield loss, quality deterioration and at the same time reducing the germination ability of kernels. Though insecticides have been used for its control, the development of new insect tolerant genotypes still remains the most feasible, attractive, cost effective and long term alternative for pest management. As resistance sources are scarce in elite maize lines, teosinte (*Zea mays ssp parviglumis*) following insect bioassay was found to be resistant and therefore used as parent in a cross with flour beetle susceptible but superior maize inbred line DI-103 for construction of backcross inbred line mapping population. Data on four resistance parameters namely, weight loss, number of insect progeny emerged, kernel damage and flour produced were collected on 141 backcross inbred lines in order to identify teosinte introgressed maize lines resistant to flour beetle infestation, to assess the degree and direction of association between different characters imparting flour beetle resistance and also to find markers linked to various quantitative trait loci (QTLs) responsible for different resistant traits. Highly significant differences were found amongst genotypes for all the parameters indicating substantial variability in the population for the traits probably contributed by teosinte. On the basis of cumulative susceptibility index, 83 lines were scored to be resistant and can be utilized as donor for flour beetle resistance in maize improvement programmes. Highly significant positive correlations were found between all trait combinations except for correlation between weight loss and kernel damage which was positive but non-significant (0.165). A total of 18 marker linked genomic regions located on all chromosomes of maize, except chromosome 5 and 6, were found to be significantly associated with red flour beetle resistance. Two major QTLs were detected on chromosome 1 and 3 for kernel damage and they explained 11.17% and 14.88% of the total phenotypic variation, respectively. Highest number of overlapping QTLs i.e., 3 were detected for kernel damage and flour produced. These linked markers after further validation can be used in future for indirect selection for resistance to red flour beetle in maize and the marker associated

with clustered QTLs can be used for effective pyramiding of different resistant alleles to breed for durable insect resistance in maize.

II-4 TRIFLOXYSTROBIN + TEBUCONOZOLE 75WG: A NEWER OPTION IN THE MANAGEMENT OF TURCICUM LEAF BLIGHT OF MAIZE IN INDIA

Mallikarjuna N., Jadesha G., Harlapur S.I., Mahadev P., Raveendra H.R. and Shivakumar B.S.
AICRP on Maize, Zonal Agricultural Research Station, V.C. Farm, Mandya
mallikmsf@gmail.com

Turcicum leaf blight of Maize is considered to be one of the most devastative disease as its occurrence and incidence assumes greater significance resulting in reduction of grain yield by 28 to 91 per cent. Presently Mancozeb is recommended for the Management of the disease. But it is losing its efficacy over the years. In view of this, field screening of new fungicides molecules against Turcuicum leaf blight was taken up during *Kharif* 2017 at Zonal Agricultural Research Station,V.C. farm, Mandya, Karnataka, India. Eight treatments were tested under natural epiphytotic condition for Leaf blight severity. Out of 8 treatments, treatment receiving Trifloxystrobin + Tebuconozole 75 WG@ 0.05% were recorded less TLB disease Intensity (10.3%) when compared to control which recorded the maximum Disease Intensity(45.0%).This was followed by the treatment receiving Tebuconozole @0.1% which recorded TLB disease Intensity (15.6%).However, the same treatments have recorded maximum disease control (77.1%) and (65.3%), higher grain yield (59.3 q/ha) and (49.1 q/ha) and per cent increase over control (96.7%) and (74.7%), respectively. However, the lowest grain yield (28.1) was recorded in untreated control.

II-5 CROSS OVER INTERACTION OF MAIZE (*ZEA MAYS* L.) INBRED LINES UNDER OPTIMAL AND DROUGHT ENVIRONMENTS

Patil N.L.[1], Shanthkumar[2] and Biradar B.D.[1]
[1]Department of Genetics and Plant Breeding, University of Agricultural Sciences, Dharwad
[2]College of Hanumanamatti, University of Agricultural Sciences, Dharwad
tryanother609@gmail.com

Maize (*Zea mays* L.) is mainly cultivated under the rainfed region in India during the kharif season and drought has become a major limiting factor for crop production due to unpredictable rainfall. Severe drought stress during flowering and grain filling stage significantly reduces the grain yield. Thus, developing drought tolerant genotypes is upmost priority of breeders in the current situation. Cross over (COI) is a type of genotype by environment (GE) interaction were genotypes show differential performance with changing location (management) i.e. change in the ranking of genotypes across location (management). A breeder is interested in this type of interaction as it determines the stability of a genotype. In the current experiment, maize inbred lines derived from elite germplasm were evaluated under two management condition drought and optimal at two locations Dharwad and Devihosur for grain yield and yield related traits during summer 2019. Drought stress was imposed by withholding irrigation after 45 days of sowing so that crop is under water stress during flowering and grain filling stage. The data from the four environments i.e. two management conditions (drought and optimal) across two locations (Dharwad and Devihosur) was subjected to statistical analysis to understand GE interaction. The mean grain yield per plant ranged from 6.8g to 99.6g under drought stress and 40g to 150.6g under optimal management across the locations. Variance analysis indicated significant differences among the inbred lines for grain yield and GE interaction accounted higher variation than genotypes as evident from the sum of squares. Thus, a GE interaction had a significant effect on grain yield of inbred lines. Spearman rank correlation is a simple statistical tool to detect COI. Low correlation coefficient indicates higher degree of COI whereas high positive correlation coefficient indicates lower COI. Rank correlation of genotypes between drought and optimal condition was -0.143 at Dharwad and -0.132 at Devihosur respectively. Similarly, the spearman rank correlation of genotypes between Dharwad and Devihosur under optimal condition was -0.085 and under drought stress was -0.153 again indicating high COI of inbred lines across locations. Further, the near right angle between the environmental vectors in the GGE biplot suggested low genetic correlation among the environments. It can be inferred that inbred lines showed high COI across management conditions and across locations. Best performing inbred lines under optimal conditions need not be best lines under drought and vice versa. There exists a huge COI of inbred lines for drought and optimal management thus, testing stability of lines should be prerequisite for developing stable hybrids for varying environments.

II-6 BIOLOGY OF FALL ARMYWORM, *SPODOPTERA FRUGIPERDA* (J.E. SMITH) ON MAIZE (*ZEA MAYS* L.)

Ahir K.C., Mahla M.K., Lekha, Chhangani G. and Sharma K.
Department of Entomology, Rajasthan College of Agriculture,
Maharana Pratap University of Agriculture and Technology, Udaipur
kcahirento@gmail.com

The biology of fall armyworm, *Spodoptera frugiperda* (J.E. Smith) was studied during *Kharif,* 2019 under laboratory conditions (26±2°C temperature and 75±5% relative humidity) at the Department of Entomology, Rajasthan College of Agriculture, MPUAT, Udaipur. The nucleus culture of FAW was initiated with the larvae collected from maize field, Agronomy farm, RCA, Udaipur and were morphologically identified. These larvae were reared on artificial diet. The freshly laid eggs from this nucleus culture were taken to study the biology of fall armyworm. After hatching, newly emerged 40 larvae were individually reared on fresh small bits of maize leaves, these leaves were changed daily as food. After the completion of larval period, the pupae were transferred gently into egg laying chambers for the emergence of the adults and the chamber were provided with 10% honey solution soaked cotton wicks placed separately in small petri plates. The female was observed laying eggs with the fecundity of 1082 eggs. The incubation, total larval (I to VI instar), pupal, pre oviposition, oviposition and post oviposition period were recorded to be from 2-3, 13-20, 8-12, 3-4, 2-3 and 4-5 days, respectively. The male and female longevity were 7-10 and 10-12 days, respectively. The total life cycle of male and female was observed to be 32-44 and 35-47 days, respectively.

II-7 EFFICACY OF FUNGICIDES, BIOPRODUCT ON THE INCIDENCE OF TURCICUM LEAF BLIGHT DISEASES OF MAIZE

Nongmaithem N., Singh S.D., Konsam J. and Senjam P.
Directorate of Research, Central Agricultural University, Imphal

Maize (Zea mays L) is the second most important crop next to rice in Manipur and it is mostly grown under rainfed and uplands conditions. In the region, maize production plays a significant role in ensuring food security and is used both for direct consumption and as well as for second cycle produce in piggery and poultry farming. Being a high humid region and the main season of maize cultivation fall in the rainy season is exposed to several biotic and abiotic stresses. Among the biotic factor, Diseases are one of the major constraints in realizing the potential yield of this crop. It suffers from a number of diseases but Turcicum leaf blight (TLB) is the most devastating leaf pathogen caused by the heterothallic ascomycete *Setosphaeria turcica* and may cause by 28 to 91% grain yield loss. The present studies were undertaken to work out the efficacy of chemicals, botanicals and bioagents for the management of TLB both under in vitro and in vivo condition for two seasons *Kharif* 2018 and 2019. Two molecules (Dithane M-45 75 WP and Azoxystrobin 18.2 w/w +Difenoconozole11.4% w/w SC), Four botanicals namely *Azadirachta indica*, *Allium sativum*, *Lantana camara* and Cow urine) and one bioagents i.e. *Trichoderma asperellum* were tested for their efficacy against TLB. Analysis revealed significant effects of Azoxystrobin 18.2 w/w +Difenoconozole11.4% w/w SC at 0.10% and *Allium sativum* (Garlic) bulb at 10% followed by *Azadirachta indica* (Neem leaves) *and Cow urine* against TLB pathogen, The slow rate of disease control virtually by the bioagents might have not shown instant effect on plant response to the yield enhancing components. The identified sources of management can be used further in strengthening the plant protection in maize against TLB pathogen.

II-8 IDENTIFICATION OF STRESS-RESILIENT MAIZE HYBRIDS ACROSS SOIL MOISTURE REGIMES: DROUGHT, WATERLOGGED AND OPTIMAL

Singamsetti A.[1], Shahi J.P.[1], Zaidi P.H.[2], Seetharam K.[2] and Kumar M.[1]
[1]Department of Genetics and Plant Breeding, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi
[2]International Maize and Wheat Improvement Centre, Asia regional office, Hyderabad
ashok.singamsetti@gmail.com

Drought and excess moisture stresses are the two major abiotic stresses limiting maize production in large part of South and South-East Asiaand many other parts of the World. Losses due to drought in lowland tropics averaged 17%and it reached up to 60% in severely drought-affected regions/seasons. In India, approximately 2.4 m ha (~ 32.4%) of total maize growing areas is prone to face drought or excess moisture stress. Breeding for stress tolerance genotypes is among the topmost priorities for countries like India which are more vulnerable in view of the huge population dependence on agriculture, excessive pressure on natural resources and poor coping mechanisms. In major parts of Asia, climate change has augmented the frequency and intensity of extreme weather conditions such as droughts, floodsand tropical cyclones. Drought tolerant maize is important focusing area in agriculture research to enhance the adaptive capacity of the third most cereal crop of the world, Maize and maize farmers to cope with the imminent threat of climate change. Stress-resilient technology, that gives high yields under optimal & resilience under drought/Heat/Waterlogging/anaerobiosis and "Guaranty of minimum" under stress, along with "claim of maximum" under optimal condition. Considering the need for maize improvement and identification of stable hybrids across different moisture conditions, present study was conducted. Experimental trials were conducted in alpha lattice designs with two replications under three different moisture regimes *i.e.* drought, water logging and optimal moisture conditions at two locations *viz*., Banaras Hindu University, Varanasi and ICRISAT Campus, Hyderabad during the growing season *rabi* 2017-18 and *kharif* 2018. Fifty medium duration corn hybrid lines including five checks were evaluated under seven environments with different soil moisture condition. The stability analysis done based on grain yield per hectare data collected from all the environments. GxE interaction, adaptability and stability parameters of the genotypes were analyzed by additive main effect and multiplicative interaction (AMMI) model using GEA-R software version 4.1 developed by CIMMYT. Imposing uniform and accurate intensity of stress at required crop growth stage was taken care for phenotyping with maximum precision. Genotypes *viz*., VH131167, ZH16929, VH123021, ZH161531, VH121082, ZH17191, ZH161529 and ZH161034 were identified as best and stable hybrids across the locations and soil moistures stresses. This report presents the results of the study, discusses climate change vulnerability and screening of stress tolerant maize hybrids which assure the growing population towards food security by enhancing the stable yields.

II-9 MONITORING OF *HELICOVERPA ARMIGERA* POPULATION USING PHEROMONE TRAPS IN MAIZE

Chitralekha and Singh M.
Chaudhary Charan Singh Haryana Agricultural University, Regional Research Station, Karnal
barwarchitralekha@gmail.com

Maize (Zea mays L.) is the third most important grain crop of the world which is widely cultivated all over the world in different agro-climatic zones. Worldwide, it is popularly known as "Queen of cereals" due to its wider adaptability and highest genetic yield potential among cereal crops. Maize is a crop of high economic significance from India's point of view. Its production and demand is continuously increasing at a higher rate as compared to other cereal crops. About 130 species of insect and mite pests have been reported damaging this crop out of which only half a dozen are of economic importance which threatens to limit the production of this crop. Major insect-pests are maize stem borer, *Chilo partellus* (Swinhoe), pink stem borer, *Sesamia inferens* (Walker), two species of shoot fly, *Atherigona nuquii* Steyskal and *Atherigona soccata* Rund, armyworm, *Mythimna seprata* (Walker) and maize cob borer, *Helicoverpa armigera* which cause economic yield losses during different seasons all over the country. The adult stage is the easiest to monitor using pheromone traps. Pheromones are sex attractants which attract only males of various species of insects. These types of trap are not used to control insects, but instead are used to monitor the population of insects. The male flight activity of the most abundant insect *H. armigera*, was investigated using pheromone trap in maize crop. This study was conducted at Regional Research Station Karnal during Kharif 2017 and 2018. Four traps were installed in one acre area commencing from 30 Days after Germination and were monitored for the adult moths at weekly interval at two

locations till harvest of the crop. Lures were changed after 4 weeks and the number of trapped adults at weekly interval were counted. During Kharif 2017, *H. armigera* pheromone traps were installed on third week of August. First trapping of *H. armigera* adult moths was reported during second week of September (37 SMW) and continued up to third week of October (42 SMW). Maximum moths were trapped during first week of October (40 SMW). During Kharif 2018, first trapping of *H. armigera* adult moths was during the first week of September (36 SMW), whereas maximum moths were trapped during third week of September (38 SMW).

II-10 PROSPECTS OF GWAS IN REVEALING GENETICS OF COLD TOLERANCE IN MAIZE

Shikha K.[1], Shahi J.P.[1], Vinayan M.T.[2], Singhamsetti A.[1] and Singh S.[1]
[1]Institute of Agricultural Sciences, B.H.U, Varanasi
[2]CIMMYT, ICRISAT, Patancheru, Hyderabad
kumarishikha1593@gmail.com

Maize is often exposed to chilling stress during Rabi planting in tropical climates. Chilling stress result in lessened plant growth rate, elongated leaf, extended stem, proliferated root and elevated production of reactive oxygen species (ROS). It is regarded as complex phenomenon which induces physiological and biochemical responses in maize at both cellular and whole-organ level. Due to different mechanisms of stress tolerance in different genotypes, the degree of chilling tolerance varies among the genotypes. To expand maize cultivation to colder regions, one of the breeding goal is to develop the cold-tolerant genotypes of maize. Primary trait such as grain yield is used to evaluate the degree of cold tolerance in maize under cold stress. Some secondary traits such as the anthesis-silking interval (ASI), plant height, pollen sterility, silk balling and grain yield components which are reported high correlation with cold tolerance and also exhibit high heritability. Therefore, these traits have been considered for selection for cold tolerance in plant breeding to identify cold-tolerant lines and underlying functional quantitative trait loci (QTLs)/genes governing cold tolerance. Genome-Wide Association Studies (GWAS) provides a robust and potent tool to retrieve the phenotypic trait back to its underlying genetics. It enable fine mapping of QTL using diverse populations as it faces large number of historical recombination events which result in the rapid decay of linkage disequilibrium (LD) Maize GWAS has resulted in successful identification of thousands of susceptible loci for common abiotic and biotic stresses complex genetic etiologies.

II-11 MONITORING OF FALL ARMYWORM *SPODOPTERA FRUGIPERDA* (J. E. SMITH) THROUGH PHEROMONE TRAPS IN MAIZE

Soujanya P.L.[1], Sekhar J.C.[1], Divya S.[1], Suby S.B.[1], Reddy M.L.[2], Yathish K.R.[1], Sunil N.[1] and Rakshit S.[1]
[1]ICAR -Indian Institute of Maize Research, Ludhiana
[2]Maize Research Centre, Professor Jaya Shankar Telangana Agricultural University, Hyderabad

Farmers in India experienced economic damage in maize due to the attack of Fall armyworm *Spodoptera frugiperda* (J. E. Smith) (Lepidoptera: Noctuidae) since its invasion in May 2018. FAW, native to Americas is a generalist feeder infest several crops including cereals, millets, cotton etc (Andrews 1988). The infestation of FAW result in yield losses of 15 to 73% when 55 to 100% of maize is infested (Hruska and Gould 1997). Seasonal air transport systems, continuous availability of hosts and favourable climatic conditions are the possible reasons for its rapid spread throughout India. Mis use of chemical insecticides result in development of resistance, resurgence and harmful effects on human health and environment. Therefore, development of ecofriendly management strategies is essential for control of FAW in a sustainable way. Integration of pheromone trap is an effective component of IPM programme which is helpful in monitoring pest population for early decision making and also for mass trapping of adults. Based on moth catches, it is easy to predict the prevailing life stages on a particular time which will direct to select the management practices against FAW. In this context, the present investigation was undertaken to monitor the activity of adult moths of FAW through pheromone traps during Rabi 2018-19 and Kharif 2019 and also studied the relationship between moth catches and weather parameters. During Rabi 2018-19, pheromone trap monitoring revealed the period of moth activity of FAW from 48th SDW (Standard Week) to 9th SDW with a peak during 51st SDW. The period of FAW moth activity ranged from 32nd SDW to 42nd SDW with a peak during 38th SDW during Kharif 2019. The correlation studies revealed that weather parameters *viz.,* maximum temperature (r=0.2709), relative humidity (r=0.5238) and rainfall (r=0.9271) were positively correlated whereas negative correlation was found with minimum temperature (r =-0.4790) in relation to moth trapping pattern. It can be concluded that pheromone trap monitoring revealed the period of moth activity of FAW and season-specific variation in the period of moth activity is attributable to various abiotic and biotic factors. Further, increasing temperature and relative humidity with slight rainfall favours population build-up of FAW.

II-12 ASSESSMENT OF AVOIDABLE LOSSES DUE TO MAYDIS LEAF BLIGHT DISEASE

Chand P., Kumar A., Alam T., Pramanick B., Kumar V. and Kumar A.
Dr. Rajendra Prasd Central Agricultural Univerisyt, TCA, Dholi

Maize is the most versatile crop, adapted to different agro-ecological and climatic conditions. Globally, it is cultivated as one of the third most important cereal crops widely grown in tropics, sub-tropics and temperate regions. In India, maize is an important cereal crop next to rice, wheat and sorghum and because of its high genetic yield potential it is known as Queen of cereals. Maydis leaf blight is a serious fungal disease of maize throughout the world where maize is grown under warm, humid condition. The present investigation on ''Assessment of avoidable losses due to Maydis leaf blight disease.'' were undertaken to work out for the knowing of avoidable yield loss due to Maydis leaf blight disease. A field trial was conducted for two years during Kharif 2018 & 2019 at Tirhut College of Agriculture, Dholi, Muzaffarpur and laid out the trial in a RBD design with 12 replications. The maize inbred line CML 186 were sown in two treatment one was protected and another unprotected. The crop was inoculated once with MLB at 30 DAS. The protected plots were sprayed with Propiconazole @ .01% for two times at 35 and 45 DAS and non-protected plots were sprayed with plain water after inoculation of the plants with pathogen. The result raveled that 15.28 per cent avoidable yield losses occur due to Maydis leaf blight disease when comprised to unprotected plots.

II-13 POTASSIUM NITRATE IMPROVED WATER LOGGING TOLERANCE OF MAIZE INBRED LINES BY MODULATING THEIR PHENOLIC METABOLISM

Ayushi L[1], Kaur K.[1] and Gill G.K.[2]
[1]Department of Biochemistry, [2]Department of Plant Breeding and Genetics, Punjab Agricultural University, Ludhiana

Water logging is a serious threat to crop productivity worldwide. It results in excessive generation of reactive oxygen species such as superoxide (O_2^-), singlet oxygen ($^1O_2$), hydrogen peroxide (H_2O_2) and hydroxyl radicals ($OH^·$) that cause oxidative damage to lipids, proteins and nucleic acids. To scavenge these reactive oxygen species, plants synthesize a number of radical scavenging molecules. Phenolics have been known to have potent scavenging ability for free radicals due to the presence of hydroxyl and carbonyl groups in their aromatic rings which impart a model structural chemistry for free radical scavenging activity. Additionally, the tolerance of plants towards water logging stress has been reported to be enhanced by the exogenous sprays of nitrogenous compounds. Foliar application of potassium nitrate has been shown to improve tolerance of plants against various abiotic stresses. Depending on these facts, the present investigation was carried out to study the effect of potassium nitrate on phenolic metabolism of maize under water logging stress. Two maize inbred lines viz., LM-11 (susceptible towards waterlogging) and I-172 (tolerant towards waterlogging) were taken for this study. The activities of guaiacol peroxidase, polyphenol oxidase, phenylalanine ammonia lyase and tyrosine ammonia lyase were determined in roots and shoots of both the inbred lines at 7th and 9th day of seedling growth stages. The contents of total phenols, flavonoids, ortho-dihydroxy phenols, lignin, hydrogen peroxide (H_2O_2) and malondialdehyde (MDA) were also determined. Our results showed that foliar spray of KNO_3 increased the activities of guaiacol peroxidase, polyphenol oxidase, phenylalanine ammonia lyase and tyrosine ammonia lyase in roots and shoots of I 172 and LM 11, under water logging stress. However, the specific activities of enzymes remained manifold higher in I-172 as compared to LM 11. The contents of phenols, flavonoids, ortho-dihydroxy phenols and lignin were also increased in both the inbred lines under water logging stress, though the levels were higher in tolerant line as compared to the susceptible one. Thus, application of KNO_3 alleviated the effects of water logging stress by regulating the phenolic metabolism in maize.

II-14 SCREENING OF MAIZE GENOTYPES FOR RESISTANCE TO STEM BORER (*CHILO PARTELLUS* SWINHOE) UNDER TEMPERATE CONDITIONS

Khuroo N.S.[1], Rasool I.[1], Wani A.R.[1], Nisar M[1]., Dar Z.A.[1], Lone A.A.[1], Sekhar, J.C[2]., Suby S.B.[2] and M.A. Wani[1]
[1]AICRP on Maize, Srinagar Centre, Shere-Kashmir University of Agricultural Sciences and Technology
[2]Winter Nursery Centre, ICAR-Indian Institute of Maize Research, Hyderabad
skhuroo0909@gmail.com

The present study were undertaken to screen maize genotypes against stem borer,

Chilo partellus (Swinhoe) and to correlate pest infestation with physico-chemical characteristics of the plant. On the basis of leaf damage score all the twenty four genotypes screened were categorized as highly resistant with score 1 which includes CM-133 and CM-123; KDM-895A, KDM-381A and KDM-362B as resistant with score 2; KDM-402 as resistant but with score 3; CM-128 and SMH-2 as moderately resistant with score 4; SMC-3, KDM72 and C-6 as moderately resistant but with score 5; KDM-914A, KDM-962A, KDM-912 and KDM-463 as susceptible with score 6; C-15, KDM-322, KDM-1263 and KDM-916A as susceptible but with score 7; KDM-340A, KDM-347, KDM-361A and KDM-935 as highly susceptible category with score 8 and Basi-local as extremely susceptible with score of 9. Quantitative analysis of leaf sheath of 24 maize genotypes were assayed at 45 DAS for total phenols and extremely susceptible genotype Basi-local with higher leaf damage score of 8.86 recorded low level of phenols 117.97 µg/g compared to highly resistant genotypes CM-123 and CM-133 suffering relatively low damage 0.86 each were found to have high total phenol content of 238.05 and 234.76 µg/g, respectively on fresh weight basis.

II-15 INTEGRATED MANAGEMENT OF POST FLOWERING STALK ROT OF MAIZE USING BIO AGENTS, FUNGICIDES AND POTASH

Mallaiah B., Bhadru D., Srilatha D., Reddy M.L. and Anuradha G.
Maize Research Center, Professor Jayshankar Telangana State Agricultural University, Hyderabad

Maize (Zea mays L.) is one of the most versatile emerging crops having wider adaptability under varied agro-climatic conditions. Maize yields are always challenged by various biotic and abiotic stresses in the world including India. Among the biotic stresses post flowering stalk rots poses a major threat to the productivity of maize crop during *Kharif* and *Rabi* seasons in Telangana state causing a yield losses of 10-40%. The experiments were conducted at Agricultural Research Station, Karimnagar during 2016 and 2017 to know the best combination of fungicide, bio agent and potash fertilizer to minimize the PFSR incidence and maximize the maize crop yield. The results reveals that among the all treatments soil application of neem cake@250kg/ha plus soil application of *Trichoderma viride* @2.5kg/ha plus application potash fertilizer @80kg/ha plus seed treatment with *Psedomonas fluorescens* @ 8g/kg seed along with foliar application of *P. fluorescens* @ 8g/l of water at knee high stage was found to be the best treatment with maize grain yield of 7859kg/ha and disease incidence of 1.7% where as the crop yield was 7157 kg/ha and disease incidence was 18.4 % in control plot. These results indicates that integration of bio agents like *T. viride, P. fluorescens,*Neem cake and potash is one of the best approach to minimize the PFSR incidence and increase the maize grain yields.

II-16 EFFECT OF LOW TEMPERATURE ON MAIZE SEED GERMINATION AND ITS RELATIONSHIP TO ANTIOXIDANT DEFENCE SYSTEM

Mishra U.[1], Gadag R.N.[1] and Elayaraja K.[2]
[1]ICAR-Indian Agriculture Research Institute, New Delhi
[2]ICAR-Sugarcane Breeding Institute, Coimbatore
upamamishra82@gmail.com

Among the cultivated cereals of huge prominence in feeding the world population, maze is unique in many ways, including wide variability and flexibility in adaptation to agroclimatic conditions. Though it is a major crop in Kharif or rainy season, cultivation during other conditions like winter season in the Indian sub-continent is assuming increasingly greater importance due to various factors. These include the demands of climate change, necessity of environment friendly. Soil health, comparatively more efficient water utilization and need for crop diversification in general. Maize seed is particularly susceptible to cold stress during germination, as low temperature adversely affects both seed emergence and seedling health. This experiment was performed to observe the effect of low temperature on maize seed germination as well as antioxidant response (total antioxidants, free amino acids, catalase and peroxidase activities) in the four maize lines. Of these, two each were derived from Pusa composite 3 and 4, (PC-3 and PC-4), initially during Rabi season 2014-2015 in IARI field at Delhi. Germination percent ranged from 25 to 80 percent. Which clearly indicated the adverse effect of low temperature on seed germination as well as viability. Cold stress resulted in significantly increased levels of total antioxidant, catalase and peroxidase. However, these increases were comparatively high in tolerant lines compared to susceptible lines. Results showed that antioxidants act as major defence against free radical mediated toxicity by protecting the damage caused by free radicals. Plants with enhanced levels of antioxidants have been reported to have greater resistance to oxidative damage. Such critical observationsand biochemical assays would help in some understanding of the probable underlying mechanisms. Continued selections and advancement of the generations during such conditions would facilitate generating useful genotypes of maize, serving as foundation for further improvement efforts. Such efforts are relevant in the context of the factors mentioned earlier and developing maize cultivars with still more flexibility and wider options to breeders and ultimately to the farmers.

II-17 DEVELOPMENT OF FIRST DROUGHT TOLERANT MAIZE VARIETY (SMC-8) IN KASHMIR: A SUCCESS STORY OF AN INTER INSTITUTIONAL APPROACH

Dar Z.A.[1], Lone A.A.[1], Naseer S.[1], Gulzafar[1], Dar S.A.[1], Alie B.A.[1], Sarkar B.[2], Sofi P.A.[1], Khuroo N.S.[1], Bidi I.A.[1], Ali G.[1], Kanth R.H.[1], Khanorkar S.M.[3], Rasool F.[1] and Rakshit S.[4]

[1]AICRP on Maize-Srinagar Centre, Shere-Kashmir University of Agricultural Sciences and Technology

[2]ICAR- Central Research Institute for Dryland Agriculture, Hyderabad

[3]Anand Agricultural University, Anand

[4]ICAR-Indian Institute of Maize Research, Ludhiana

In Kashmir Valley maize is grown as a sole crop at an altitude range of 1560-2250m above mean sea level. Lack of potential varieties (composites & hybrids) having genes for moisture stress tolerance is one of the major reasons for low maize productivity in Kashmir as compared to state average yield of 1.96 tonnes. The climate change scenario has further complicated the situation and the maize growing period is invariably dry from the last 5-10 years. This warrants development of drought resilient varieties to increase the adaptive capacities of poor farmers that are inherently lacking and are highly vulnerable to climate change implications. Drought tolerant varieties are the most economical approach that can help farmers to overcome the challenges posed by risks of climatic variabilities especially frequent droughts. Shalimar Maize Composite-8 (SMC-8) a white kernel variety developed using the SMART CROSS STRATEGY performed exceedingly well over locations under moisture stress conditions and was accordingly promoted for release on account of its exceptional drought tolerance attributes. The variety represents a pilot model of effective integration of screening modules to develop products that can be immediately pushed into the farming systems and help the resource poor farmers to reap the benefits of improved products across challenging ecologies.

II-18 GENETIC ANALYSIS IN MAIZE (*ZEA MAYS L.*) FOR VARIOUS MORPHO-AGRONOMIC TRAITS UNDER TEMPERATE CONDITIONS

Dar Z.A.[1], Lone A.A.[1], Naseer S.[1], Rasool F.[1], Dar S.A.[1], Habib M.[1], Khuroo N.S.[1], Ali G.[1], Abidi I.[1], Kumar B.[2], Khulbe R.K.[3], Bashir S.[1], Nissa S.[1], Rashid Z.[1] and Hakeem S.A.[1]

[1]AICRP on Maize, Srinagar Centre, Shere-Kashmir University of Agricultural Sciences and Technology

[2]ICAR- Indian Institute of Maize Research, Ludhiana

[3]ICAR-Vivekanand Parvatiya Krishi Anunsandhan Sansthan, Almora

The present study was aimed to assess the general combining ability of parents and specific combining ability of their crosses for yield and yield related traits. Eight inbred lines were crossed with three testers using line × tester mating design. The resulting twenty-four crosses along with eleven parents were evaluated at two locations during *Kharif* 2018 in a completely randomized block design. The parent KDM-445A was identified as best combiner for grain yield plant^{-1} followed by CM-502 and KDM-347. Besides, KDM-445A was also accompanied with significant and desirable gca for 100 grain weight, grain depth, shelling percentage, protein content, number of kernels row^{-1}, days to 50 per cent tasseling and days to 50 per cent silking. Among the crosses, KDM-347 × SMC-7, KDM-445A × DMR-N6 and V-351 × DMR-N6 exhibited highly significant and desirable SCA effects for grain yield plant^{-1}. Therefore, these crosses can be utilized for developing high yielding hybrid varieties in maize under temperate conditions

II-19 DEVELOPMENT OF ABIOTIC STRESS RESILIENT MAIZE GENOTYPES UTILIZING HIGH THROUGHPUT PHENOMICS APPROACH

Dar Z.A.[1], Lone A.A.[1], Rane J.S.[2], Naseer S.[1], Dar S.A.[1], Kanth R.H.[1], Sofi P.A.[1], Khuroo N.S.[1], Khan J.A.[3], Abidi I.[1], Ali G.[1], Rasool F.[1], Haq S.A.[1], Lone B.A.[1] and Rakshit S.[4]

[1]AICRP on Maize-Srinagar Centre, Shere-Kashmir University of Agricultural Sciences and Technology

[2]ICAR-National Institute of Abiotic Stress management, Baramati

[3]University of Agriculture Sciences, Bangalore

[4]ICAR- Indian Institute of Maize Research, Ludhiana

Phenomics is an emerging science aimed at non-destructive methods that allow large scale screening of genotypes, thereby complementing genomic efforts to identify genes relevant for crop improvement under both favorable and unfavorable

environments. Thirty maize inbred lines from different sources (exotic and indigenous) maintained at Dryland Agriculture Research Station (SKUAST- Kashmir) were chosen for the study. In the automated conveyer for plant transport and imaging systems (the ICAR-NIASM LemnaTecScanalyzer system for large plants), top and side view images were taken of the VIS and NIR range of the light spectrum. The Lemnagrid Integrated Analysis software for high-throughput plant image analyses was used for image-based plant feature extraction. Image processing is divided into two major parts: image segmentation and feature extraction. All thermal images were obtained with a thermal imager (Vario CAM hr Inspect 575, Jenoptic, Germany). The results introduced a dataset of 30 maize inbred lines. Images were collected daily for 11 days. Imaging started one day after shifting the pots from the greenhouse. Different surrogates were estimated in the study such as area, plant aspect ratio, convex hull ratio, caliper length, etc. A strong association was found between canopy temperature and above ground biomass under stress conditions. Lines showing promise in different surrogates should be crossed with locally adapted lines to develop mapping populations for traits of interest related to drought resilience, in terms of improved tissue water status and map genes/QTLs of interest.

II-20 EVALUATION OF CANOPY TEMPERATURE DEPRESSION AND RELATIVE WATER CONTENT AS INDICATORS FOR DROUGHT TOLERANCE IN MAIZE (*ZEA MAYS* L.) INBREDS

Islam N.U.[1], Ali G.[2], Dar Z.A.[3], Rafiq S.[4], Bhat A.[5] and Nagoo S.A.
[1]Division of Genetics and Plant Breeding, FoA, Wadura, Sopore, SKUAST-Kashmir
[2]Division of Genetics and Plant Breeding, Shalimar, SKUAST-Kashmir
[3]Dryland Agriculture Research Station, Budgam, SKUAST-Kashmir
[4]Division of Entomology, SKUAST Jammu
[5]Division of Entomology, FoA, Wadura, Sopore, SKUAST Kashmir
[6]TSRI, Mirgund, SKUAST-Kashmir

Drought denotes a period without appreciable precipitation, during which the soil water content is reduced to such an extent that plants suffer from lack of water. Drought tolerance is a complex trait involving morphological, physiological and biochemical mechanism. Physiological changes due to moisture stress, which reflect an adaptive mechanism in genotype, are worth measuring for relative assessment of differences. Leaf RWC is a reliable indicator of leaf water deficit status at the time of sampling. It is often used to examine the response of a plant to the progress of drought stress. CTD is a direct function of evapotranspiration rate which is determined by a number of physiological and metabolic processes. CTD becomes a suitable selection criterion under heat stress environment. This study was conducted to determine the effect of water stress on CTD and RWC to evaluate drought tolerance of maize inbreds. Thirty maize inbreds were evaluated in greenhouse experiment based on completely randomized design with three replications at two irrigation levels (well-watered and moisture- stressed). Inbreds CML-470, DMR-N6, CML-415 and LM-12 had cooler canopies under drought conditions. The difference between CTD under irrigated and drought conditions was small initially (1.20) but increased progressively at 2nd week of stress imposition (1.70) and was highest at 3rd week of stress imposition (2.70) in all maize genotypes. CTD can be used to assess plant water status because it represents an overall, integrated physiological response to drought and high temperature. High CTD can be used as a selection criterion to improve tolerance to drought and heat. RWC under drought conditions recorded highest value in DMR-N6 followed by L-9 and V-335. The rate of RWC in plant with high resistance against drought is higher than others. In other words, plant having higher yields under drought stress should have high RWC. Relative water content can be said to be a good parameter suitable to screening drought-tolerant maize varieties

II-21 SCREENING FOR DROUGHT TOLERANCE OF MAIZE (*ZEA MAYS* L.) INBREDS UNDER *IN-VITRO* RESPONSE TO PEG

Islam N.U.[1], Ali G.[2], Dar Z.A.[3], Rafiq S.[4] and Bhat A.[5]
[1]Division of Genetics and Plant Breeding, FoA, Wadura, Sopore, SKUAST-Kashmir
[2]Division of Genetics and Plant Breeding, Shalimar, SKUAST-Kashmir
[3]Dryland Agriculture Research Station, Budgam, SKUAST-Kashmir
[4]Division of Entomology, SKUAST Jammu
[5]Division of Entomology, FoA, Wadura, Sopore, SKUAST Kashmir

Drought is the most important abiotic stress affecting maize crop production worldwide. Drought is defined as the mechanism causing minimum loss of yield in a water deficit environment relative to the maximum yield in a water constraint free management of the crop. Drought is the primary abiotic stress causing not only differences between the mean yield and the potential yield but also causing maize yield instability. Drought is the most pervasive limitation to the realization of yield potential in maize. The selection of tolerant lines for drought in maize depends largely on efficient selection criteria. To stabilize the production for year to year, emphasis should be given to the screening and identification of genotypes under artificially created moisture stress condition, which is pre-requisite to achieve the goals of high yield and moisture stress tolerance. PEG is a superior chemical to induce water stress. Polyethylene glycol (PEG) molecules are inert, non-ionic, virtually impermeable chains and have been used frequently to induce water stress in crop plants. Poly ethylene glycol (PEG) has been used often as abiotic stress inducer in many studies to screen drought tolerant germplasm. The germplasm which has better growth under stressed environment may have drought tolerance mechanism in it and these plants may have capability of holding a homeostasis under stressed conditions. The germplasm which is showing better performance can be considered as drought tolerant. An experiment was carried out to study the effect of Polyethylene glycol (PEG) at different levels 0% (control), 5%, 10% and 20%) on the root parameters like primary root length, number of seminals roots , number of lateral roots and root biomass of 30 maize (*Zea mays* L.) inbreds to screen them for drought tolerance. The experiment was carried out in four replicates under factorial Complete Randomized Design. All the root parameters had highest value under control and had significant decline with increasing PEG concentrations (0% < 5% < 10% < 20%). The inbreds having genetic potential to maintain the higher growth under stress conditions are drought tolerant. The variation among maize inbreds for these traits was found to be a reliable indicator to screen the drought tolerant genotypes at primary growth stage.

II-22 IDENTIFICATION OF SOURCES OF RESISTANCE AGAINST *TURCICUM* LEAF BLIGHT OF MAIZE UNDER HIGH ALTITUDE CONDITIONS OF KASHMIR

Nasseer S.[1], Dar Z.A.[1], Ahangar M.A.[1], Lone A.A.[1], Nair S.[1], Rashid Z.[1], Kumar B.[2], Rasool F.[1], Majid S.[1], Bashir S.[1], Rasool Z.[1], Nisa S.[1], Hakeem S.[1], Nagoo S.[1] and Habib M.[1]
[1]AICRP on Maize, Srinagar Centre, Shere-Kashmir University of Agricultural Sciences and Technology
[2]ICAR- Indian Institute of Maize Research, Ludhiana

Tursicum Leaf blight also known as Northern Corn Leaf blight in maize is caused by fungus *Exserohilum turcicum* (Pass.) Leonard and Suggs. It is economically the most important disease affecting maize in the world and frequently occurs in high altitude ecologies of Kashmir. A set of 100 germplasm lines of maize belonging to CIMMYT, SKUAST-K and IIMR Ludhiana were screened under artificial inoculation conditions during *Kharif* 2017-2018. The experiment was carried out at MCRS Larnoo located at an altitude of 2300 m amsl. Test lines were planted in 2 row plot of 3 m length with a spacing of 60X 20 cm. The mixed inoculation of 20 day old culture of 4 isolates of *Exserohilum turcicum* from Larnoo and Khudwani locations were utilised. The genotypes viz. VL-1018641, VL-108665, VL- 05614 and VL -102 showed resistance reaction with disease grade 1 against *Exserohilum turcicum* whereas remaining genotypes showed moderate resistance to susceptible reaction . The genotypes Pahalgam Local and SMI 154 were found highly susceptible. To validate resistance, the genotypes need further evaluation under controlled conditions against all the available isolates of *Exserohilum turcicum.*

II-23 GENETIC POTENTIAL OF HILL MAIZE GERMPLASM FOR GRAIN YIELD AND ITS COMPONENT TRAITS

Chandel U.[1], Guleria S.K.[2] and Mankotia B.S.[1]
[1]Shivalik Agriculture Research and Extension Centre, Kangra
[2]Hill Agriculture Research and Extension Centre, Bajaura
Chaudhary Sarwan Kumar Himachal Pradesh Krishi Vishva Vidyalaya
uttam_chandel@yahoo.co.in

The development of new cultivars depends mainly on the magnitude of genetic variability in the base material for the desired character. The knowledge of genetic variability, heritability and genetic advance in a given crop species is of paramount importance for the success of any plant breeding programme. With this objective, 40 maize inbreds developed from local germplasm along with three checks (LM 13, LM 14 and CM-212) were evaluated in a randomized complete block design with two replications at Experimental Farm of Shivalik Agricultural Research and Extension Centre, Kangra during *Kharif* 2018. Inbreds were kept open for random mating. Data were collected on days to anthesis and silking, anthesis-silking interval, plant and ear heights, ear length (cm), ear diameter (cm), number of rows/cob, 1000-grain weight (g) and grain yield per plant. The analysis of variance revealed significant differences between genotypes for all the considered traits. High magnitude of phenotypic and genotypic coefficient of variations as well as high heritability along with high genetic advance as percent of mean were observed for grain yield/plant, 1000-grain weight, ear length, ear diameter, no of rows/cobs, plant and cob heights provides evidence that these parameters were under the control of additive gene effects and effective selection could be possible for the improvement of these characters, whereas, days to anthesis, days to silking and anthesis-silking interval recorded lower estimates of heritability in broad sense and genetic advamce, indicated non-additive gene action and provides limited scope for improvement through selection. Inbreds *viz.*, KI-3, KI-7, KI-17, KI-28, KI-29, KI-35 and KI-36 had less ASI (1 to 4 days) and recorded (> 20 %) higher yield than the best check. These selected inbreds could be effectively used for enhancing maize yield.

II-24 PEST SUCCESSION OF MAJOR INSECT PESTS INFESTING MAIZE

Vyas A., Chhangani G. and Mahla M.K.
Department of Entomology, Rajasthan College of Agriculture, Maharan Pratap University of Agriculture and Technology, Udaipur
vyasdr2004@gmail.com

The experiment on incidence of pest succession of insect pests in *Kharif*, sown maize was conducted at Agronomy Farm, RCA, Udaipur. The weekly observations after germination revealed that major insect pests infesting maize in Udaipur region were maize stem borer, fall armyworm (FAW), aphids, chafer beetle and termite. The peak population of maize stem borer was found in third week of august to first week of September; whereas, fall armyworm in second week of September. The maximum population of aphids as well as chafer beetle were recorded: while, termite population peaked in fourth week of September to throughout crop season.

II-25 MAIZE DISEASE SITUATION IN WESTERN MAHARASHTRA

Shinde V.S.[1], Dhonde S.R.[1], Latake S.B.[2] and Kute N.S.[2]
[1]AICRP on Maize, [2]Pulses Improvement Project
Mahatma Phule Krishi Vidyapeeth, Rahuri
shindevs27@gmail.com

The survey was conducted in maize growing areas of Western Maharashtra for recording occurrence of various diseases. During *kharif* 2018-19 the intensity of diseases *viz*., Turcicum leaf blight, Maydis leaf blight and charcoal rot was observed from trace to low. The incidence of false head smut [*Ustilaginoidea virens* (Cooke) Takahashi] disease was noticed on maize crop in Nadurbar district during October, 2018 and a perusal of literature revealed that it was the first report from Maharashtra. The fungus infected male florets in the tassel at flowering stage and florets were converted in large, velvety, green balls (pseudomorphs) which were more than twice the diameter of normal florets. The ball surface was covered by powdery dark-green chlamydospores, conidia and mycelia. Microscopic observations revealed that, conidia were round to elliptical with rough surface and 3-6 µm in diameter. During *kharif* 2019-20 the diseases *viz*., Turcicum leaf blight, Maydis leaf blight and rust were observed in surveyed areas of Ahmednagar, Nasik, Jalgaon and Dhule districts. However, intensity of these diseases was traces to low.

II-26 SCREENING OF MAIZE RIL POPULATION FOR HIGH TEMPERATURE STRESS TOLERANCE

Kaur S.[1], Kumar R.[2], Das A.K.[2], Kaur Y.[2], Sharma P.[3], Moghiya A.[2] and Rakshit S.[2]

[1]Department of Plant Breeding and Genetics, Punjab Agriculture University, Ludhiana
[2]ICAR-Indian Institute of Maize Research, Ludhiana
[3]School of Agricultural Biotechnology, Punjab Agriculture University, Ludhiana

Maize is mainly a *kharif* season crop and ideal temperature for maize cultivation is 10-33°C. Due to global warming temperature is increasing and increased temperature is identified as one of the major threat to maize production. Keeping in mind the emerging threat of increased temperature for maize cultivation an experiment was conducted to screen a RIL population derived from the cross between normal maize lines DML 1276 × DML 1343 having 143 lines of F6 stage. The material was planted in three replications in α-Lattice design at two locations i.e. Ludhiana and Delhi during spring season, 2019. The sowing was done in 2nd week of March to expose the population to high temperature at the time of flowering. The temperature during first week of May (flowering time) was more than 40°C, which causes tassel blasting and leaf firing resulting non-setting of grains or cause barrenness. However some lines namely 62, 23, 15, 46, 90, 68 and 19 recorded good grain yield at such a high temperature and these lines are considered as heat tolerant lines whereas majority of the lines failed to set grains or a very few grains were recorded and these lines are considered as susceptible lines. Further, these lines will be genotyped for identification of genomic regions responsible for heat stress tolerance so that we can transfer the QTL's in elite breeding lines.

II-27 DYNAMICS OF MAIZE DISEASES AND THEIR MANAGEMENT UNDER CHANGING CLIMATE SCENARIO

Harlapur S.I., Salakinkop S.R., Kachapur R.M., Walli M.C. and Naidu G.K.
AICRP on Maize, University of Agricultural Sciences, Dharwad
harlapursi@gmail.com

Maize is the one of the most important cereal crops in Karnataka and is widely grown in various climatic conditions across the state. The occurrence and severity of diseases and resultant losses are dependent on the prevailing agro climatic conditions and hybrids grown in an area. The importance and magnitude of severity and loss depends on interaction between host and pathogen under a given set of environment conditions. Diseases of importance known at present like TLB, PFSR, common rust and polysora rust will continue to represent problems in certain conditions. Other diseases like, BLSB, CLS, MLB. Diplodia ear rot and Brown spot were not previously known as limiting factors, but now identified as new challenges in maize production in Karnataka. Diseases viz., Banded leaf and sheath blight (*Rhizoctonia solani* f. sp. *sasakii),* seedling blights (*Exserohithum turcicum* and *Fusarium* sp.) Curvularia leaf spot (*Curularia lunata*) and Ear rots (*Diplodia maydis. (Syn. Stenocarpella maydis),*) were predominantly prevalent in heavy rainfall with hot and humid climatic areas of hilly and transitional zones. High foliar diseases severity may be attributed to extensive and continuous cropping of maize and cultivation of susceptible hybrids. The increasing trend in disease severity of maize can be attributed to late sowing (late July to August) due to irregularity to rainy season. The crop sown during September was subjected to severe incidence of foliar diseases. The foliar and stalk rot diseases were more aggravated wherever the farmers have practices maize monocropping and maize- sorghum sequence. Extended periods of very dry or wet weather prior to pollination followed by an abrupt change for several weeks after silking favors the development of stalk rot fungi. High nitrogen levels combined with a low level of potassium also responsible for increased stalk rot incidence in some places. Sowing done a week or ten days before usual date of the break of monsoon with initial one or two protective irrigations provides a better practice for the establishment of plants, lowers disease severity and yield increases 15-20 per cent. Use recommended seed rate so as to maintain optimum plant population. This is an important factor in reducing stalk rots, lodging foliar disease and ear rots. Corp rotation should be done on a regular basis, failure to rotate maize leads to increased losses from several diseases including foliar disease, stalk rots (PFSR) and soil borne diseases. Maize can be rotated with wheat, soybean, bengalgram, green gram, groundnut in a one year rotation under irrigated and assured rainfall situations. It can be grown in rotation with cotton and sugarcane in a two year rotation. For the management of seed rot, seedling blight and PFSR, seed treatment with Carbendazim @ 2 g/kg seed or Thiram Flo 40 SC @ 5 ml/kg seed or *Trichoderma harzianum* @ 6 g/kg seed bioagent provides good control measures. BLSB can be managed by seed treatment with biogent, *Pseudomonas fluorescence* @ 10 g/kg seed followed by foliar spray with Propiconazole @ 0.1% at 45 DAS. Foliar diseases can be effectively managed by foliar application of Tebuconazole 250 EC @ 1 ml/1 or Azoxystrobin + Difenconazole @ 1 ml or Propiconazole 25 EC @ 1 ml/l. Brown spot is managed by foliar application of Benomyl @ 0.1% or Vitavax @ 0.2%. Resistant hybrids along with chemical control measures provides effective strategy to combat the losses due to diseases.

II-28 MANAGING ABIOTIC STRESSES: A KEY ROLE IN PRECISION PHENOTYPING FOR CLIMATE RESILIENT MAIZE (*ZEA MAYS* L.)

Shahi J.P., Singamsetti A, Shikha K. and Madankar K.
Department of Genetics and Plant Breeding
Institute of Agricultural Sciences, Banaras Hindu University, Varanasi
jpshahi1@gmail.com

Rising demand for maize and declining productivity due to the effect of various abiotic stresses, which are expected to increase with global climate change as temperatures rise and alteration in rainfall distribution in key traditional production areas of the country may leads to triple the maize imports by 2050. To overcome the situation, developing climate resilient maize cultivars which ensure stable yields along maximum mean yield across the environments is the primary aim of the maize technologists. For this, taking up of managed stress experiments is mandatory. Large scale controlled stress environments are now considered essential for further development of stress tolerant maize lines. Imposing abiotic stresses such as drought (water deficit), waterlogging (excessive soil moisture), heat/high temperature and cold/chilling stress at the target stage of crop growth is the keystone factor for precision phenotyping to evaluate the genotypes across the environments. Stress timing, Stress intensity and Stress uniformity are the basic principles for monitoring stress. Flowering stage in maize is the critical stage and responsible for greater yield losses due to various abiotic stresses. Drought stress can be imposed by pausing irrigation at 550 GDD (Growing degree days) value and resuming irrigation at 1000 GDD value in a trial with moderate to long duration corn genotypes. Besides, GDD values, moisture stress can be managed more accurately by vapour-pressure deficit or

VPD values (withholding irrigation between 120 and 220 VPD values) and moisture probe data. Limiting irrigation at Knee high, Flowering and Grain filling stages under field condition, Rain-out shelter technique, SPAD meter observations and Green Seeker Optical Sensor are also used to confirm their tolerance to drought. In excess moisture experiments, waterlogging treatment applied at 'Knee high stage' (V_6-V_7 growth stage) continuously for seven days and then draining out of excess water must be done from seventh day. Days to 50% anthesis, days to 50% silking, anthesis silking interval (ASI), mortality per cent, lodging, chlorophyll content, senescence, leaf rolling, stay-green, number of nodes with brace roots and surface roots are the crucial phenotypical traits under soil moisture stresses. Heat and cold stress strongly impair growth and development of maize plant during tasseling, silking and grain filling stage. A primary trait, grain yield is used to evaluate the degree of cold tolerance in maize under cold stress. Some secondary traits such as the anthesis-silking interval (ASI), pollen sterility, silk balling and grain yield components which are reported greater correlation with cold tolerance and also exhibit high heritability. Planting time is important aspect in the heat and cold stress experiments which ensures that required temperatures must coincide with the target crop growth stage to evaluate the stress tolerant levels. Characters *viz*, tassel blast, senescence, leaf firing, pollen fertility, stay-green and lodging per cent are the responsible traits for greater yield loss in heat stress experiments.

II-29 PHYSICO-CHEMICAL BASES OF RESISTANCE IN SPRING MAIZE AGAINST SHOOT FLY, *ATHERIGONA NAQVII* STEYSKAL IN NORTH INDIA

Goyal S.[1], Jindal J.[2] and Kaur K.[3]
[1]Department of Entomology, [2]Department of Plant Breeding and Genetics,
[3]Department of Biochemistry, Punjab Agricultural University, Ludhiana
sunitgoyal96@gmail.com

Shoot fly, *Atherigona naqvii* Steyskal is a major biotic constraint to spring sown maize in northern India. The host plant resistance is one of the most promising alternatives to insecticides to manage this pest. In present studies, nineteen maize inbreds selected from diverse sources were characterized for resistance traits against shoot fly under natural infestation using moistened fish at Punjab Agricultural University, Ludhiana during spring 2018 and 2019. The antixenosis to shoot fly for oviposition was not observed in the test genotypes. The antibiosis and tolerance were recognized as key mechanisms of resistance. Antibiosis was reported in terms of significantly prolonged larval (10.17–11.18 days) and pupal (8.45–8.86 days) periods; lower larval (55.90–58.49%) and pupal (54.92–64.89%) survival; and less larval (3.30–3.77 mg) and pupal (3.25– 3.54 mg) weight, in resistant genotypes. Whereas, the susceptible genotypes, SE 563 and LM 16, displayed significantly shorter larval (8.72–9.33 days) and pupal (7.66–7.85 days) periods; higher larval (77.69–81.54%) and pupal (69.72–71.09 %) survival; and more larval (3.91–4.04 mg) and pupal (4.20–4.33 mg) weight. Tolerance to shoot fly, measured in terms of less proportion of deadhearts out of shoot fly incidence (leaf injury+deadhearts), was significantly more in resistant inbreds, SO1SHYQBBB13B, HK12-6-2-4, DMSC 28, CM 143 and Winpop 8 (29.46–36.56%) in comparison to the susceptible genotypes SE 563 and LM 16 (46.31–47.44%). More seedling vigor, less leaf area and thin stem were significantly and positively correlated with resistance to shoot fly. Among biochemical parameters, contents of total soluble sugars (TSS), proteins and amino acids were higher in the susceptible inbreds and these were found associated with the susceptibility to shoot fly. Whereas the contents of phenols and tannins; and activities of phenylalanine ammonia lyase (PAL) and polyphenol oxidase (PPO) were higher in resistant inbreds and had significant deleterious effects on shoot fly survival and development. The stepwise regression revealed that the deadhearts were significantly influenced by seedling vigour (R2= 65.2%), leaf area (R2= 7.5%) and number of leaves per plant (R2= 2.8%). The larval period, per cent pupation, pupal weight female, pupal weight male and adult emergence of shoot fly were significantly influenced by PAL activity, which explained 71.5, 82.9, 47.0, 29.8 and 39.9 per cent of their total variation, respectively. PPO activity significantly influenced the pupal period (R2= 59.7%). Larval weight was significantly influenced by amino acids (R2= 56.9%), proteins (R2= 10.2%) and TSS (R2= 7.7%). These physico-chemical characters of the maize inbreds can be utilized as reliable markers traits to develop shoot fly resistant maize hybrids.

II-30 FALL ARMY WARM, WEED AND BIO-ECONOMIC DYNAMICS IN TRADITIONAL MAIZE AND LEGUMES INTERCROPPING SYSTEM

Salakinkop S.R., Shridhar H. S. and Harlapur S. I.
AICRP on Maize, Main Agricultural Research Station,
University of Agricultural Sciences, Dharwad
salakinkopsr@uasd.in

The present investigation encompassing traditional maize and legume intercropping systems in various patterns conducted at Main Agricultural Research Station, University of Agricultural Sciences, Dharwad, Karnataka, India, revealed that the maize equivalent yield was significantly higher in maize + blackgram (1:1) with 75 cm × 20 cm spacing (73.3 q ha^{-1}). The higher land equivalent ratio (1.4) and area time equivalent ratio (1.2) was recorded in maize + blackgram (1:1) with 90 cm × 20 cm spacing. Significantly higher system productivity index was also observed in maize + greengram (1:1) with 75 cm × 20 cm spacing (431.4). Fall army worm infestation was higher on sole maize (5.7 %) as compared to the intercropping system. Among the intercropping system fall army worm least infestation under maize + greengram at 1:2 row ratio in 90 cm × 20 cm spacing (1.7 %) followed by maize + greengram at 1:1 row ratio in 75 cm × 20 cm spacing (1.9 %) (Table 5). Crop diversity with legumes reduced fall armyworm infestation and supports natural enemies (parasitoids and predators). Similarly, sole maize recorded higher weed density (38.90 and 52.13 m^{-2} at 30 and 60 DAS respectively) and weed dry matter (26.57 and 42.10 g m^{-2} at 30 and 60 DAS respectively). Whereas, significantly lower weed density (22.83 and 35.10 m^{-2} at 30 DAS and 60 DAS respectively) and weed dry matter (10.43 and 14.00 g m^{-2} at 30 and 60 DAS respectively) observed in maize and cowpea intercropping of 1:2 row ratio with 90 cm × 20 cm spacing (Table 4). The high suppression ability of the cowpea could be due to early canopy cover and smoothening ability results in lower availability of space and light leads to lower down the density of weeds and ultimately recorded lower weeds dry weight in intercropping. Significantly higher gross, net returns and B-C ratio was recorded in 1:1 row ratio at 75 cm × 20 cm spacing of maize + blackgram (₹1,44,516 ha^{-1}, ₹88,668 ha^{-1} and 2.59) and it was on par with all other intercropping systems except maize + cowpea at 1:1 and 1:2 row ratios in 90 cm × 20 cm spacing (Table 6). The increased gross returns, net returns and B-C ratio were mainly due to better performance of component crops, which have higher equivalent yield and higher market price of maize (₹ 1850 ha^{-1}), greengram (₹ 5229 ha^{-1}) and blackgram (₹ 4955 ha^{-1}). Significantly lower gross and net returns were recorded in sole greengram (₹ 55,479 ha^{-1} and ₹ 21,388 ha^{-1} respectively).The results are corroborated with the findings of Artika *et al*., 2017 who reported significantly higher gross returns (₹ 1,41,593 ha^{-1}), net returns (₹ 1,21,719 ha^{-1}) and B-C ratio (7.12) under clusterbean + cowpea (2:2) intercropping system. Most of the intercropping competitive functions and bio-economics were favourable under maize + blackgram and maize + greengram in 1:1 row ratio at 75 cm × 20 cm and hence; it would be most advantageous sustainable maize production cropping system in South India.

II-31 EFFICACY OF NEWER INSECTICIDES AGAINST MAIZE STEM BORER *CHILO PARTELLUS* SWINHOE INFESTING MAIZE IN *KHARIF* MAIZE IN SOUTHERN RAJASTHAN

Swami H., Chhangani G. and Mahla M.K.
Department of Entomology, Rajasthan College of Agriculture,
Maharana Pratap University of Agriculture and Technology, Udaipur
hemantswamy@gmail.com

The field experiments on evaluation of efficacy of insecticides *viz*., Chlorantaniliprole 20 SC @ 0.3 &0.4 ml/litre, Flubendiamide 480 SC @ 0.1 &0.2 ml/litre, Novaluron 10 EC @ 0.75 &1.0 ml/litre and Deltamethrin 2.8 EC @ 0.4 ml/litre against *Chilo partellus* was conducted under artificial infestation conditions at Rajasthan College of Agriculture during 2015. The results revealed that the application of Flubendiamide 480 SC @ 0.2 ml/litre at 4 days after artificial infestation gave lowest LIR of 1.06 followed by Flubendiamide 480 SC @ 0.1 ml/litre at 4 days after artificial infestation and were found promising for stem borer management. The Flubendiamide 480 SC at half dosages proved most effective against the *C. partellus* followed by the Chlorantaniliprole 20 SC @ 0.3 &0.4 ml/litre. The treatment application of Novaluron 10 EC @ 0.75 &1.0 ml/litre of water were next effective treatment against of *C. partellus*. the application of Flubendiamide 480 SC @ 0.2 ml/litre resulted in higher grain yield as compared to other treatments at harvest during 2015.

II-32 VALIDATION OF STABLE DISEASE RESISTANCE IN MAIZE INBREDS AGAINST *PERONOSCLEROSPORA SORGHI* INCITANT OF DOWNY MILDEW DISEASE

Jadesha G.[1], Mallikarjuna N.[1], Mahadevu P.[1], Lohithaswa H.C.[2] and Swapna G.[1]
[1]AICRP on Maize, Zonal Agricultural Research Station, V.C. Farm, Mandya
[2]Department of Genetics and Plant Breeding, College of Agriculture, V.C. Farm, Mandya
University of Agricultural Sciences, Bangalore

Downy mildew (DM) in maize caused by *Peronosclerospora sorghi* is a systemic disease causing significant yield loss in the maize growing areas. Identification and utilization of stable resistant sources are very crucial in resistance breeding programme and ultimately managing the disease effectively. The study was conducted during *Kharif*-2018, *Rabi*-2018-19 and *Kharif*-2019 comprises of 10 resistant inbreds *viz*., MAI 1, MAI 2, MAI 3, MAI 7, MAI 8, MAI 10, MAI 12, MAI 13, MAI 16, MAI 20 and one susceptible composite CM 500. Experiment was conducted in randomized block design with three replications. The study revealed that, among all ten inbreds MAI 1, MAI 10, MAI 12, MAI 13 and MAI 20 have showed the complete resistance with nil incidence of disease whereas susceptible check CM 500 has recorded the incidence of 79.7 Per cent. Further MAI 2, MAI 3, MAI 7, MAI 8 and MAI 16 have recorded the incidence of 3.9, 3.7, 4.0, 12.8and 4.1 respectively. Among all, nine inbreds have showed the resistance (R) reaction with incidence less than 10 per cent whereas MAI 8 has showed the moderate resistance (MR) with incidence of 12.8 per cent.

II-33 EVALUATION OF MAIZE GENOTYPES UNDER IRRIGATED AND HEAT STRESS ECOLOGIES

Moghiya A.[1], Kumar R.[1], Kaur Y., Jat S.L.[2] and Rakshit S.[1]
[1]ICAR-Indian Institute of Maize Research, Ludhiana
[2]Delhi Unit Office, ICAR- Indian Institute of Maize Research, New Delhi

Maize is cultivated in diverse agro climatic conditions of the world and it is third most important crop after rice and wheat. Genotype × environment interaction always an important role in production of any crop and maize requires optimum temperature (10-33^{0}C) for its growth and development. On the other side, increasing temperature impairs growth and development of maize plant. This study was conducted to evaluate 18 genotypes under optimum and heat stress conditions at Ludhiana in kharif and spring, 2019 to assess their performance under differential environments. Material was planted in two replications in RBD experimental design. For heat stress conditions, sowing was delayed and planting was done on 15th of March to expose the crop to high temperature during flowering stage. Temperature during the flowering period varied between 37-45^{0}C and no significant rainfall was recorded. High temperature causes reduction in grain setting and eventually grain yield decreases. Some of the genotypes showed good performance under both the environments viz. ZH 1799, ZH 17165, ZH 17153, ZH 16135 and ZH 191078 by showing least yield reduction and stable grain yield even under stressed conditions. Whereas, some genotypes i.e. ZH 191081, ZH 1783, ZH 16162, ZH 16418 and ZH 17123 showed high reduction in yield. G × E interaction plays a vital role in differential expression of genotypes. Best performing lines can further be evaluated under more diverse ecologies over the years. The lines which were best across the environments can be used as donors in development of hybrids for high temperature tolerance under a suitable environment or as testers in assessing the performance.

II-34 EVALUATION OF SEED TREATMENT AGAINST *CHILO PARTELLUS* INFESTING MAIZE

Mahla M.K., Chhangani G., Vyas A. and Singh B.
Department of Entomology, Rajasthan College of Agriculture
Maharana Pratap University of Agriculture and Technology, Udaipur
mkmahla@yahoo.co.in

The experiment to evaluate the efficacy of insecticides *viz*., Thiamethoxam 30 FS @ 6.0 ml, 8.0 ml and 10.0 ml/kg seed, Imidacloprid 600 FS @ 4.0 ml, 6.0 ml and 8.0

ml/kg seed, Chlorpyriphos 20 EC @ 5.0 ml/kg seedand Fipronil 5 SC @ 6.0 ml/kg seed against *Chilo partellus* infesting maize under artificial infestation conditions was conducted during Kharif, 2017 at Agronomy Farm, RCA, Udaipur. The observations were recorded at 30 days after artificial infestation in terms of leaf injury rating 1-9. The results revealed that the LIR ranged from 3.67-5.87 in different treatments. The lowest LIR 3.67 was recorded in treatment application of Thiamethoxam 30 FS @ 10.0 ml/kg seed followed by 4.06 and 4.13 in treatment Thiamethoxam 30 FS @ 8.0 ml/kg seed and Imidacloprid 600 FS @ 8.0 ml/kg seed, respectively. The maximum borer infestation was recorded in application of Chlorpyriphos 20 EC @ 5.0 ml/kg seed, with LIR 5.87. The application of Thiamethoxam 30 FS @ 6.0 ml/kg seed, Imidacloprid 600 FS @ 6.0 ml and 4.0 ml/kg seed and Fipronil 5 SC @ 6.0 ml/kg seed LIR rating was 4.20, 4.60, 4.67 and 5.20 respectively. Highest LIR rating 7.13 was recorded in untreated control.

II-35 FIELD EVALUATION OF MAIZE HYBRIDS FOR RESISTANCE TO TURCICUM LEAF BLIGHT

Devlash R. and Guleria S.K.
Chaudhary Sarwan Kumar Himachal Pradesh Krishi Vishva Vidyalaya,
Hill Agricultural Research and Extension Centre, Bajaura, Kullu
devlashbajaura@rediffmail.com

Maize (*Zea mays* L.) is one of the most important *kharif* cereals of Himachal Pradesh. It is mainly used as food, feed and fodder in the state and is grown over a wide range of agro-climatic conditions. Diseases are an important constraint for maize production in the state. The crop is affected by number of fungal diseases of which northern corn leaf blight (NCLB) or turcicum leaf blight (TLB) caused by *Exserohilum turcicum* is one of the important diseases causing severe reduction in grain yield to an extent of 28 to 91%. Turcicum leaf blight (TLB) affects the maize crop from the seedling stage to maturity. Cultivation of resistant genotypes is the most economical and safer option to manage this disease. Therefore, the present study involved 15 maize hybrids of private and public sector for resistance against NCLB. Field trials were conducted during *kharif* season of 2018 at CSK Himachal Agricultural University, Hill Agricultural Research and Extension Centre, Bajaura. Maize hybrids were planted during second fortnight of June in paired rows of 3 meter length in two replications by adopting recommended package of practices. Plants were inoculated with pathogens by dropping a pinch of inoculum consisting of ground powder made from infected leaves of the previous season's crop in the whorl in thirty five days old plants followed by spray of water after inoculation in order to maintain high humidity. The disease severity of maize hybrids was assessed using 1-9 disease scoring scale. Data on disease were recorded at weekly intervals, starting from the appearance of disease and that of yield (q/ha) at harvest. All the maize hybrids were found resistant/ moderately resistant against NCLB. Disease score of resistant hybrids varies from 2-3 with yield levels 9.0 – 11.8 t/ha. Maize hybrids Vyas Gold, HP 33 Gold, B-52 Gold, B-52 Super, PSC3322 Gold, PG2500, PSC 4445, NMH1277 and DKC 8181 were found promising.

II-36 CURRENT STATUS OF DISEASE RESISTANCE SOURCE OF MAIZE IN INDIA

Olakh D.S.[1], Hooda K.S.[2], Bagaria P.K.[1], Aggarwal S.K.[1], Nara U.[3], Mohit[1], Kumar R.[1] and Rakshit S.[1]
[1]ICAR-Indian Institute of Maize Research, Ludhiana
[2]ICAR-National Bureau of Plant Genetic Resource, New Delhi
[3]Punjab Agricultural University, Ludhiana

Maize is an important cereal crop after rice and wheat across the world. However this crop is affected by many diseases like Turcicum leaf blight, Maydis Leaf Blight, Banded Leaf and Sheath Blight, Common Rust, Charcoal Rot, Polysora Rust, Sorghum Downy Mildew, Curvularia Leaf Spot, Bacterial Stalk Rot, Rajasthan Downy Mildew, Fusarium Stalk Rot and Brown spot. In experimental fields, the losses caused by these diseases have been recorded from time to time *viz*., TLB 13-50 %, MLB 15-46 %, BLSB up to 60 %, C Rust 18-49 %, C Rot 25-32 %, SDM up to 100 %, CLS %, BSR up to 85 %, RDM 10-60 %, FSR10-42 %, Brown spot up to 6-20 %. In this article we have reviewed the losses caused by different diseases under artificially created epiphytotic conditions. The losses caused by these diseases are very high and have negative impact on Indian economy. The efforts are being made identify resistance sources and their use in breeding programmes. In India, 442 maize cultivars have been released for cultivation at farmer fields and 103 resistant/tolerant germplasm lines have also been registered for different diseases with NBPGR since 1964 to till date. This germplasm is available for resistance breeding programme or further genetic studies. Hence, it is suggested that the resistance sources identified till date might be revalidated with the help of molecular tools and the resistance genes/genomic regions might be identified and transferred to elite germplasm.

II-37 MANAGEMENT OF IMPORTANT MAIZE DISEASES OF CENTRAL WESTERN ZONE IN INDIA

Aggarwal S.K.[1], Hooda K.S.[2], Bagaria P.K.[1], Sharma S.S.[3], Baheti B.L.[3], Rathore B.S.[3], Mohit[1], Olakh D.S.[1] and Rakshit S.[1]
[1]ICAR- Indian Institute of Maize Research, Ludhiana
[2]ICAR- National Bureau of Plant Genetic Resource, New Delhi
[3]Maharana Pratap University of Agriculture and Technology, Udaipur
sumit.aggarwal009@gmail.com

Post-Flowering Stalk Rot (PFSR), Curvularia Leaf Spot (CLS) and Cyst Nematode (CN) are major threats of maize in the Central Western Zone of India particularly in Rajasthan. A field study was conducted to evaluate the effective component to manage these threats. A total of six and seven treatments were applied for management of Post-flowering stalk rot (PFSR) and Curvularia leaf spot (CLS) diseases including fungicides, bio-agents and botanicals respectively. In case of PFSR, Out of six treatments, bioagent *Trichoderma viride* in 100 Kg FYM was found most effective with 78.34% disease control followed by, Propiconazole @ 0.1% spray at 40 days (77.89% disease control). In case of CLS, seed treatment with fungicides combination of Carbendazim +Mancozeb @0.25% as well as spray at 45 and 65 DAS @ 0.2% found most effective with 70.0% disease control followed by, Alliete ST @4g/Kg seed and FS at 45 and 60 DAS @ 0.2% (68.0% disease control).To manage the cyst nematode, four biocontrol agent with different concentration were applied as seed treatment. Out of these, bioagent *Glomus fasciculatum* 4% w/w showed maximum reduction (51.33 %) in females/5g root and Cyst/100cc soil (49.32%)

followed by *Metarrhizium anisopliae* 4% w/w (41.59 % reduction in females/5g root and 41.32 % reduction in Cyst/100cc) . These effective components can be validated and used as effective management strategies of mentioned threats.

II-38 GENERATION MEAN ANALYSIS FOR INHERITANCE OF NORTHERN CORN LEAF BLIGHT RESISTANCE IN MAIZE (*ZEA MAYS* L.) IN NORTH EASTERN HILL CONDITIONS OF INDIA

Bharali V. and Sen D.
School of Crop Improvement, College of Post-Graduate Studies
Central Agricultural University, Umiam

Maize is an important cereal crop with high genetic variability that enables it to cope up with climate change. By exploiting this, the biotic and abiotic factors causing threat to maize production can be managed. The current study was undertaken to elucidate the nature of gene action of the foliar disease Northern Corn Leaf Blight (NCLB) caused by the hemibiotroph *Setosphaeria turcica* which limits maize production globally. The plant material comprised of lines developed from different landraces collected from North East Hill Region of India. For carrying out Generation Mean Analysis (GMA) breeding populations comprising of F_2 and backcross generations (BC_1 and BC_2) were developed. Following artificial inoculation (4 x 10^3 conidia/ml) at knee height crop stage at average temperature of 22- 25^{o}C and relative humidity of 80% and above, resistant components Area under Disease Progress Curve (AUDPC) and Percent Disease Severity (DS) scores were studied for all six generations of the crosses *viz*. RM16 x YS1, RM17 x YMA4 and RM7 x RT24. Scaling test (Mather, 1949) and Joint scaling test (Cavalli, 1952) performed to determine the presence or absence of non-allelic interaction indicated inadequacy of additive-dominance model for all the three crosses. Analysis of gene effects based on the six parameter model studies indicated that gene action was primarily population specific. Highly significant mean effects for both resistance parameters studied implied that NCLB inheritance was under polygenic control in all the three crosses. The mean values of F_2 generation for crosses RM17 x YMA4 and RM7 x RT24 were intermediate of their respective backcrosses implying that the parents were highly diverse with respect to NCLB resistance. Overall, predominance of additive variance observed coupled with variable gene effects indicated that the resistance components studied were fixable in nature for developing inbreds through identification of transgressive seggregants or through family selection for heterosis breeding programme.

II-39 APPROACHES FOR THE SELECTION OF MAIZE INBRED LINES FOR DROUGHT TOLERANCE BREEDING PROGRAMME EMPLOYING PHYSIOLOGICAL AND YIELD ATTRIBUTES ENDORSED WITH STRESS TOLERANCE INDICES

Vasmatkar P[1], Kaur K.[1] and Gill G.K.[2]
[1]Department of Biochemistry, [2]Department of Plant Breeding and Genetics
Punjab Agricultural University, Ludhiana
vasmatkar-bcm@pau.edu

The present study was aimed at identifying drought tolerant maize inbred lines on the basis of their physiological and yield related attributes and various stress tolerance indices. Ten maize inbred lines were sown in the field under irrigated and drought conditions. An evaluation of the stress tolerance indices showed that LM 13, CM 143 and CM 144 had high stress tolerance index, mean productivity, geometric mean productivity, yield index, drought resistance index and harmonic mean. LM 15, CM 139 and CM 140 had high stress susceptibility index, tolerance index and stress susceptibility percentage. Pearson correlation coefficient showed a negative correlation between anthesis silking interval and yield related attributes. 3D-diagram showed that LM 13 had the highest stress tolerance index while LM 15 had the lowest value under drought. Principal component analysis classified the inbred lines into four groups with LM 13, LM 15 and CM 140 occupying distinct positions. Wards cluster analysis also showed that LM 13, LM 15 and CM 140 were distantly apart from each other. It may be concluded that LM 15 and CM 140 were drought sensitive lines while LM 13 and CM 143 were drought tolerant lines with high yield.

II-40 FIELD EFFICACY OF SOME BIO-PESTICIDES IN MANAGEMENT OF *CHILO PARTELLUS* (SWINHOE) IN MAIZE

Singh J.M.[1], Kumar A.[1] and Chitarlekha[2]
[1]Chaudhary Charan Singh Haryana Agricultural University, Rice Research Station, Kaul
[2]Chaudhary Charan Singh Haryana Agricultural University, Regional Research Station, Karnal
jaglanms@gmail.com

Maize (*Zea mays* L.) is the most versatile crop with wider adaptability in varied agro-ecologies and has highest genetic yield potential among the food grain crops. In India, maize is the most important cereal after wheat and rice. It is a multipurpose crop, providing food and fuel for human, feed for poultry and livestock and have a great nutritional value. Inclusion of maize in rice-wheat growing areas is a useful proposition. Therefore, it is emerging as a potential driving force for diversification. In India, it occupies an area of 9.63 million hectares having annual production of 25.90 million metric tonnes with average productivity of 2.69 metric tonnes per hectare (Anonymous, 2018). In Haryana, it is grown over an area of 11000 hectares having production of 30000 tonnes with average productivity of 2.73 t/ha (Anonymous, 2014). Maize productivity of India is 2.62 t/ha against the world average of 5.79 t/ha. A number of factors are responsible for this low productivity, out of which insect-pests and diseases are among major constraints. In India, about 13.2 per cent economic yield losses have been reported due to insect-pests attack and disease incidence (Anonymous, 2014).Maize crop is subjected to attack by over 130 insect pests during different stages of its growth. However, only about a dozen are quite serious (Siddiqui and Marwaha, 1993). Amongst different insect-pests, maize production is severely affected by maize stem borer, *Chilo partellus* to the degree of 15 -60 per cent. A loss of 24-75 per cent has been reported by the attack of this pest alone (Kumar, 2002). Management of *C. partellus* is indispensable for successful cultivation of maize. Use of insecticides is not the right choice to control this pest due to its cryptic behaviour of feeding inside the stem. Moreover, extensive use of chemical insecticides directly increases the cost of cultivation and possesses many health hazards. The attempts to control insects have changed over time from chemicals to natural control methods. Among the various natural control methods, bio-pesticides have received considerable attention as a viable alternative to chemical pesticides. The study was therefore, conducted to assess the bio-efficacy of fungi based bio-pesticides viz. *Beauveria bassiana* (Bb-5a, Bb-23 and Bb-45), *Metarhizium anisopliae* (Ma-35) @ 10 ml/l water, bacterial formulation, Delfin 5 WG @ 5 g/l water, botanical *neem* formulation @ 5g/l water and compared with Monocrotophos 36 SL @ 1.25 ml/l water and untreated control. Studies were carried out in the laboratory and research farm of the CCSHAU, Regional Research Stationand Karnal during *Kharif,* 2016 to 2018. In all eight treatments, maize genotype (HPQM 1) was shown in four rows of three meter row length at spacing of 75×20 cm and replicated thrice. The plants were infested artificially. Larvae of *C. partellus* were collected from infested maize plants in field at National Diary Research Institute, Karnal during month of May to generate nucleus culture for mass rearing. Out of the four rows, middle two rows were artificially infested with *C. partellus*. The plants were infested with 10-15 black head stage eggs at 12-15 DAG in all treatments. First spray of the bio- pesticides/insecticide was done two days after the infestation and second spray 10 days after first spray. LIR (1-9 scale) was recorded 25 days after infestation on 1-9 scale as given by Sarup *et el*., 1978. Grain yield at harvest was recorded. Results revealed that among different bio-pesticides, Delfin 5 WG @ 5 gm/l water was found superior to all other tested bio-pesticides. Minimum leaf injury rating (3.10) was observed minimum in Delfin 5 WG @ 5 gm/l water and it differed significantly with Bb-5a *B. bassiana*, Bb-23 *B. bassiana,* Bb-45 *B. bassiana,* Ma-35 *Metarhizium and neem* formulation. Maximum grain yield (55.65 Q/ha) was also observed in Delfin 5 WG @ 5 gm/l water and was found at par with Monocrotophos 36 SL @ 1.25 ml/L water and *neem* formulation @ 5g/l water. Grain yield of all bio-pesticides treatments was found superior over untreated control except *Beauveria bassiana* Bb-5a and *Metarhizium anisopliae* Ma-35 @ 10 ml/l water. Amongst the bio-pesticides, Delfin 5 WG @ 5g/l water has shown promise in alleviating the infestation of maize stem borer in maize crop.

II-41 MANAGEMENT OF FALL ARMYWORM, *SPODOPTERA FRUGIPERDA* (J E SMITH) IN GRAIN AND FODDER MAIZE IN PUNJAB

Cheema H.K., Jindal J., Kumar S., Aggarwal N., Chawla J.S. and Sharma U.
Department of Plant Breeding and Genetics, Punjab Agricultural University, Ludhiana
hkcheema@pau.edu

Fall armyworm *Spodoptera frugiperda* (JE Smith) is a destructive pest, native to Americas. It primarily feeds on maize followed by sorghum and pearl millet. It causes elongated papery windows on leaf lamina, ragged-edged holes and in later instars, extensive leaf damage that can limit green fodder yield as well as damage tassel and corn ear in grain maize. Keeping this in view. Insecticides Chlorantraniliprole18.5 SC @ 0.4 ml/litre, Emamectin benzoate 5 WG @ 0.4 g/ litre and Spinetoram 11.7 SC @ 0.5 ml/litre spray were evaluated alongwith Bt formulation (Delfin) @ 2 g/litre and untreated control in both grain and fodder maize during late *kharif* 2019. The trials were conducted at farmer's fields on grain maize at Fazilka and on fodder maize at Kharar, Ludhiana and Jalandhar. The spray fluid of 200 litres per acre for each chemical was used in trials. The incidence of fall armyworm was recorded in 100 fresh whorls per replication before spray, 5 and 10 days after spray (DAS). Similarly, the larval counts were recorded from 10 infested plants per replication at different observation times. The yield of grain and fodder maize was also recorded on the marked area for different treatments. In trial on grain maize, the incidence of FAW in fresh whorls ranged from 12.20-16.20% in various treatments before spray. Five DAS, the incidence in insecticide spray plot was 2.20- 2.60 per cent, which was significantly better than Bt formulation spray (9.0%) and untreated control (12.2%). Similarly trend was observed 10 DAS. The larval counts before spray varied from 1.84-2.40 per 10 infested plants. Five and ten days after spray the counts in insecticide spray plots varied from 0.14-0.18 and 0.16- 0.18 per 10 infested plants, which was significantly better than Bt formulation spray (1.06 and 0.98) and untreated control (1.66 and 1.28 per 10 infested plants, respectively). The incidence of FAW in fresh whorls in fodder maize before spray varied from 9.33 – 27.00 per cent. Five days after spray, the incidence in insecticide spray plot varied from 1.33- 5.00 per cent across the locations, which was significantly better in reducing the incidence than Bt formulation spray (7.67-18.33%) and untreated control (12.67- 23.33%). Similarly trend was observed 10 DAS. The larval counts of FAW in fodder maize at different locations before spray varied from 6.33 – 9.33 per 10 infested plants. Five days after spray the counts in insecticide spray plots varied from 0.67-3.33 per 10 infested plants across the locations, which was significantly better in reducing the larval population than Bt formulation spray (4.33- 6.33) and untreated control (6.33 - 9.67 per 10 infested plants). Similarly, 10 DAS the larval counts in insecticide spray plots was significantly lower (0.33- 1.67) than the Bt formulation spray (2.67- 5.67) and untreated control (3.00-10.33 per 10 infested plants). The pooled data on fodder maize revealed similar trend for the incidence as well as larval counts. The grain yield was significantly more in insecticide treated plots (46.5-46.8q/ha) in comparison to Bt spray (41.3) and untreated control (39.7q/ha). The green fodder yield was also significantly more in insecticide treated plots in comparison to Bt spray and untreated control. On pooled basis, the green fodder yield was 255.78- 262.88 q/ha in insecticide treated plots as compared to 213.99 q/ha in Bt spray and 209.84 q/ha in untreated control. Overall, the results indicated that all the three insecticides effectively managed the fall armyworm incidence at their respective doses.

II-42 MAJOR DISEASES OF MAIZE AND THEIR PROMINENCE IN HARYANA

Singh H., Chauhan P. and Soni N.
Chaudhary Charan Singh Haryana Agricultural University, Regional Research station, Uchani, Karnal
harvinderrao@yahoo.co.in

Maize (*Zea mays* L.) occupies third most important place as a food crop in the world agricultural economy after wheat and rice. In India, the maize in grown in Karnataka, Rajasthan, Madhya Pradesh, Bihar, Punjab, Haryana and Andhra Pradesh during *kharif, rabi* and spring seasons. Diversification efforts are made by the government to increase the maize area in *kharif* season and to discourage the paddy-wheat cropping pattern to save underground water in Haryana. The specialty corn such as sweet corn and baby corn also getting popularity in the NCR region. The regular disease incidence has always been a challenge to grow healthy crop during the *kharif* season. Among the various diseases, maydis leaf blight (MLB), banded leaf and sheath blight (BLSB) and curvularia leaf spot (CLS) are reported to cause significant yield losses in *kharif* season. The survey conducted during *Kharif* 2018 and 2019 indicated the regular incidence of these diseases from traces to moderate scale in major maize growing districts of Haryana, *viz.*, Karnal, Kurukshetra, Sonepat, Ambala, Panchkula and Yamunanagar. The per cent disease intensity of MLB was observed medium to high in all the districts during 2018. Similarly, BSLB incidence was low to medium and CLS was in traces to low. During 2019 incidence of MLB and BLSB was low to medium in scale. Incidence of CLS was low in Karnal and Kurukshetra, whereas, in other districts the disease was observed in traces. The survey indicated that Haryana prevails more conducive conditions for MLB and BLSB. The regular survey and monitoring will help to emphasis agricultural practices to combat the challenges of crop loss due to diseases and mitigate the problem by following better package of practices.

II-43. FINE MAPPING OF FUSARIUM STALK ROT RESISTANCE QTL qFSR3.1 AND ITS UTILIZATION IN MAIZE BREEDING PROGRAMME

Saini S.[1], Lalit[1], Vikal Y.[2], Chawla J.S.[1], Kaur H.[1]
[1]Department of Plant Breeding and Genetics, [2]School of Agricultural Biotechnology,
Punjab Agricultural University, Ludhiana, Punjab
sssandeep742@gmail.com

Maize stalk rot is one of the most devasting soil- borne fungal disease caused by a number of pathogens out of which *Fusarium verticillioides* is most prevalent in the northwest India. Yield losses due to Fusarium Stalk Rot (FSR) varies from 10 to 42% and can be as high as 100% in some areas. The disease is difficult to control by chemical methods, therefore, host plant resistance is important for controlling the disease. Segregation analysis of 190 recombinant inbred lines (RILs) in F_8 and F_9 derived from a cross between LM5 (resistant parent) and CM140 (Susceptible parent) clearly indicated quantitative mode of inheritance of the disease. Through composite interval mapping, a novel resistance QTL on chromosome 3 of maize flanked by SSR markers umc2118-bnlg1647 explaining 23.07 per cent of phenotypic variance was identified, conferring resistance to FSR. Genetic distance between reported markers associated with FSR resistance QTL was 20 cM. The objective of this study was to fine map the earlier identified QTL to narrow down the region and investigate the gene or genes underlying resistance to FSR. New SSR markers were designed in the predicted region using MISA. Using newly synthesized SSR markers, the region was narrowed down from 20 cM to 6 cM, flanked by PAUS_7 and PAUS_10. This study also indicated that under Punjab conditions, spring season is more prone to *Fusarium verticillioides* infection than kharif. Newly identified linked markers for resistance to FSR can be further used in marker assisted selections (MAS) and the resistant lines derived from this cross can also be used in breeding programmes to improve resistance for Fusarium Stalk Rot.

II-44. DEVELOPMENT OF CLIMATE RESILIENT MAIZE GENOTYPES AND GENOME-WIDE IDENTIFICATION OF MIRNA PLAYING ROLE IN DROUGHT AND WATER LOGGING STRESS TOLERANCE

Kumar B.[1*], Kumar K.[1], Singh S.B.[1], Gami R.[2], Kumar S.G[3]., Sravani D[4]., Soundhini[5], Kumar S.[1], Singh B.K.[1], Meenakshi[1], Singh V.[1], Choudhary M.[1], Kumar P.[1], Pushpender[1], Jha A.[1], Chaturvedi G.[1]and Rakshit S.[1]

[1]ICAR-Indian Institute of Maize Research, Ludhiana
[2]Sardarkrushinagar Dantiwada Agricultural University, Bhiloda
[3] University of Agricultural Sciences, Dharwad
[4] Professor Jayashankar Telangana State Agricultural University, Hyderabad
[5] Tamil Nadu Agricultural University, Coimbatore
bhupender.iimr@gmail.com

In India, around 80% of maize is still cultivated in rainfed ecologies that are more prone to abiotic and biotic stresses due to their unpredictable and highly variable weather patterns, topography and soil conditions. Research experiments were carried out at multiple sites (total 8) for evaluation of maize genotypes under managed drought and water logging stresses in field conditions during kharif 2017 (using 42 hybrid), kharif 2018 (83 hybrids), and kharif 2019 (6 hybrids). The drought stress was imposed at flowering stage however; water logging was imposed at knee height stage. For drought stress, the irrigation was stopped completely for 17-20 days (10 days before/7-10 days after the initiation of flowering). The water logging stress was imposed by stagnating water in field at knee height stage continuously for 10 days. The data was recorded on all important shoot parameters, flowering, and yield and its components traits. Potential hybrids identified for drought tolerance were CMH 12-686, CMH 08-292, PMH5, DMRH1417, and DMRH1419 and water logging were CMH 08-287, CMH 08-292, IMH1527, and DMRH1419. These potential hybrids identified better during various year/seasons of testing were yielding ranges from 4.0 t/ha to 6.9 t/ha in the drought and water logging stresses, respectively. There were sufficient and well developed aerenchyma found in the water logging tolerant hybrids comparing to the susceptible ones. These hybrids were also validated by demonstrating them on large plots in farmer and experimental field. Further, 130 diverse inbred lines were also evaluated for water logging and drought stresses under glass house conditions and the suitable lines identified as water logging tolerant were DML-221, DQL-593-4, DQL-785-1-8, CML 409, CML 40BBB and for drought tolerance, DQL-574-2, CML 420, DML-221, VL109126, and CAL14138. The 164 new diverse inbred lines and 6 BC_1F_1 families have been developed from using drought tolerant and wild relatives, respectively, as donors for normal elite inbred lines background. NGS for miRNA was carried out in root and shoot of susceptible and tolerant genotypes to identify key regulatory elements for the target stresses. Total 134 known and 75 novel miRNAs in water logging and 49 known and 76 novels in drought stress were identified as differentially expressed in roots and/or in shoot tissues. These results may be useful for development of functional markers for abiotic stresses breeding programme. The new genotypes developed may be utilized in breeding climate resilient maize hybrids and identified hybrids may be recommended for cultivation in stress prone ecologies.

II-45. *IN VITRO* INTERACTION STUDIES OF PLANT PATHOGENIC AND GROWTH PROMOTING BACTERIA WITH ZINC OXIDE NANOPARTICLES SYNTHESIZED THROUGH VARIOUS CHEMICAL SYNTHESIS APPROACHES

Tondey M., Kalia A. and Singh A.[‡]
[*]Department of Microbiology, College of Basic Sciences and Humanities
[†]Electron Microscopy and Nanoscience Laboratory, Department of Soil Science, College of Agriculture, Punjab Agricultural University, Ludhiana

‡ICAR-Indian Institute of Maize Research, PAU Camus, PAU, Ludhiana

Maize (*Zea mays* L.) is third largest cereal crop for grain production after wheat and rice in India. However, maize growth and yield is affected by a variety of abiotic and biotic factors. Bacterial stalk rot caused by *Dickeya zeae,* is responsible for substantial losses in *Kharif* sown maize crop due to aggravation of the disease symptoms during subsequent monsoon rainfall coinciding with a susceptible growth stage in maize. The aim of the present study was to synthesize zinc oxide nanoparticles (ZnONPs) via chemical precipitation and sol-gel methods followed by their evaluation for antibacterial potential against plant pathogenic *Dickeya* isolate (obtained from diseased maize plant) and plant growth promoting soil rhizobacteria, *Azotobacter* sp. The ZnONPs were synthesized using following reducing agents, *viz.,* natural polymers (starch, cellulose, potato-extract), bovine serum albumin, and thiourea while zinc acetate and zinc chloride were used as salt precursors. The synthesized ZnONPs exhibited quasi-spherical shape and their average particle size was less than 100 nm as characterized by Transmission Electron microscopy (TEM). The UV-Vis spectroscopy of ZnONPs showed characteristic absorption peak(s) lying between 190-800 nm wavelength. The FT-IR spectroscopy of the synthesized ZnONPs depicted presence of specific functional groups. Further, the antibacterial activity of the synthesized ZnONPs was evaluated against *Dickeya sp.* and *Azotobacter sp.* A higher antibacterial activity was recorded against *Dickeya sp.* as compared to *Azotobacter sp.* Therefore, these ZnONPs appeared to exhibit differential antibacterial activity against plant pathogenic bacteria as compared to the test soil PGPR. Apart from antimicrobial potential, the free radical scavenging or antioxidant activity of various prepared ZnONPs as determined through DPPH radical scavenging method was observed to be vary considerably. Among these nanoparticles, the sol-gel derivative nanoparticles showed highest free radical scavenging activity. Thus, this study accentuates the particle size and concentration dependent variability in the antioxidant and antibacterial properties of the synthesized ZnONPs against test phytopathogenic and PGPR bacteria.

II-46. MANAGEMENT OF FALL ARMY WORM ON MAIZE IN THE STATE OF TELANGANA-AN IPM STRATEGY RECOMMENDED

Reddy, M.L.K.[1]., Omprakash, S[1]., Rajinikanth, E[1]., Sai Charan, M[1]. and Lakshmi Soujanya P.[2]

[1]Maize Research Centre, PJTSAU, ARI, Rajendranagar, Hyderabad

[2.] Winter Nursery Centre, ICAR-Indian Institute of Maize Research, Hyderabad

Fall army worm (FAW), *Spodoptera frugiperda* (J E Smith) (Lepidotera, Noctuidae) is native of United States of America (Florida and Southern Texas). It is regular and serious pest of maize (Corn) particularly sweet corn is more preferred. It was reported in West and Central Africa in 2016 and later on it was reported in India on maize in Shivamogga district of Karnataka in 2018 (NBAIR, Bangalore). Soon after, ICAR-NBAIR has issued pest alert in India on July 30. Its incidence was also reported from Telangana State on *Kharif* maize ranged from 3-60% and 30.8% during *Rabi* 2018-19. Larval samples collected across the state were identified as *Spodoptera frugiperda* by ICAR-NBAIR. Control measures suggested by CIMMYT and FAO for management of Fall Army Worm in African countries (2016) was validated on pilot basis at Maize Research Centre and communicated strategy for management of this pest in

Telangana State on maize. Four IPM modules were tested at different locations viz., RARS Jagtial, ARS Karimnagar and ARS, Tornala during *Rabi* 2018-19. The results revealed that, all IPM modules tested were found to be effective against Fall Army Worm over control at all the locations. The reduction in pest infestation was ranged from 29.7 to 63.0% and reduction in severity of damage was from 26.6 to 52.0% over control 70% and 65% respectively. The cost benefit ratio was highest in Module 4 (2.74). i.e., seed treatment with Imidacloprid 600 FS@4 ml/kg seed followed by Chlorantraniliprole18.5 SC @0.3ml/l at 20 DAG and or Spinetoram 11.7SC @0.5ml/l at 30 DAG ,then Poison bait with thiodicarb 75% WP @100 g/ acre before flowering. An IPM strategy was communicated to the Department of Agriculture for management of Fall Army Worm during *Kharif*, 2019 based on the results of research done during the year 2018-19 i.e., summer ploughing, Intercropping with redgram, green gram, black gram or cowpea 2:1 ratio, selection of single cross hybrid, seed treatment with Imidacloprid 600 FS or *Cyantraniliprole 19.8% + Thiomethoxam* 19.8% @ 4 ml per kg seed, Erection of pheromone traps @ 4/acre soon after sowing for monitoring, Erection of bird perches @ 15/acre during early stage of the crop, application of balanced fertilizers (NPK @80:24:20), clean cultivation upto 45 DAS, as general or common practices to all maize farmers. Further, on observation of FAW at First window (0 to 30 days old crop): Whorl application of Neem formulation (Azadiractin, 1500ppm) @ 5 ml /l of water soon after observation of egg laying, whorl application of Emamectin benzoate 5 SG 0.4 g per liter of water soon after observation of early instar larvae (5-10% damage) and or whorl application of Chlorantraniliprole 18.5% SC @ 0.4 ml/l or Spinetoram 0.5 ml/l of water (damage >20%) or Release of *Telenomus remus* or *Trichogramma pretiosum* @ 50,000/ac at weekly intervals (soon after observation of egg masses in the field) and Whorl application of *Metarhizium* @ 5 g/liter of water or Application of Sand+lime (9:1 ratio) in whorl @ 10 kg /acre. Second window, Mid whorl to late whorl stage (31-65 old crop): If necessary apply above said control methods (1st window) one or two times for management of FAW in 2nd window or Apply poison bait in whorls for the control of grownup larvae with thiodicarb@100 g/ac (10 kg rice bran + 2 kg jiggery + 2-3 l of water, after mixing thoroughly keep for fermentation and then mix 100 g of thiodicarb). Third window Flowering to grain hardening stage (>65 old crop): Insecticide management is not cost effective at this stage, Hand picking and killing of larvae is the best option. crop losses can be minimized by taking up timely control measures in 1st & 2nd window, as it is the venerable stage of the crop.

II-47. DEVELOPMENT OF CHARCOAL ROT OF MAIZE CAUSED BY *MACROPHOMINA PHASEOLINA* IN RELATION TO WEATHER VARIABLES AND WATER STRESS

Kaur H. and **Ahmadi K.**

[1]Department of Plant Breeding and Genetics, Punjab Agricultural University, Ludhiana

[2]Department of Plant Pathology, Punjab Agricultural University, Ludhiana

harleenkaur@pau.edu

Macrophomina phaseolina causing charcoal rot is a major constraint in the drier region of India and yield reduction is estimated to the tune of 63.5 percent. The effect of five different sowing dates on disease severity of charcoal rot of five maize hybrids during spring 2018 and 2019 revealed that crop sown on 20th January suffered minimum disease severity (40.91 and 36.3 %) resulting in maximum grain yield (74.27 and 77.89 q/ha) during spring 2018 and 2019 respectively. The plant height and cob height was found maximum on this date. As sowing date was delayed, severity of charcoal rot increased, thus decreasing grain yield, plant height and cob height. Among meteorological factors, disease severity was found positively correlated with mean temperature and negatively correlated with mean relative humidity and total rainfall. Multiple regression equation depicting all the dependent variables revealed that when there was increase in one unit of mean temperature the percent disease severity increased by 6.08 percent. However, increase in one unit of rainfall will lead to 0.42 percent decrease in disease severity. The effect of three irrigation schedules (additional irrigation at tasseling and silking stage, local practice and stress at tasseling and silking stage) on the development of charcoal rot showed that application of an additional irrigation at tasseling and silking stage had least mean disease severity (36.28%) compared to other irrigation schedules and resulted in highest mean grain yield (72.61 q/ha). Water stress at tasseling and silking stage of the crop aggravated the disease development. Thus it can be concluded that inoculating the plant at most susceptible stage, delayed sowing and water stress at flowering and tasseling stage predisposes the plant to charcoal rot during spring season in Punjab.

II-48. PROFILING OF LOW-NITROGEN STRESS RESPONSIVE MIRNAS IN MAIZE USING HIGH-THROUGHPUT SEQUENCING

Kumar A., Aggarwal C., Kumar K., Singh S. and Yadava P.
ICAR- Indian Institute of Maize Research, Pusa Campus, New

The post green revolution agriculture is based on generous application of nitrogen (N)-based fertilizers and high-yielding genotypes. Generally, plants cannot utilize more than 40% of the applied nitrogenous fertilizer; hence more than half of the applied fertilizer is lost to the environment and results in environmental pollution via acidification, eutrophication, and depletion of ozone layer by emission of greenhouse gas. Therefore, genetic improvement in nitrogen use efficiency (NUE) in crops is desirable for a sustainable and profitable agriculture. There is a need to identify key regulatory factors playing pivotal role in acquisition, transportation and utilization of N in plants. Among other factors, microRNA (miRNA) mediated gene regulation plays a crucial role in controlling low N stress adaptation and tolerance in plants. In this endeavor, the present study was undertaken to identify N stress responsive miRNAs in maize in tropical maize using high-throughput sequencing. The HKI-163 maize inbred line was grown hydroponically with sufficient nitrogen (2mM) and without nitrogen for 21 days. Observations were recorded on all important shoot and root physiological parameters. The root and shoot samples were deep sequenced for miRNA study. The expression analysis revealed 23 known miRNAs (11 up & 12 down-regulated) in leaf and 3 known miRNAs (1 up & 2 down-regulated) in root, which expressed differentially under N stress. We also identified 53 (20 up & 33 down-regulated) and 26 (9 up & 17 down-regulated) novel miRNAs in leaf and roots respectively. The knowledge gained will help understand the important roles that miRNAs play in maize, while responding to a nitrogen limiting environment.

Theme-III

Production & Quality Improvement under Climate Change

III-1. NON- SETTING OF GRAIN IN MAIZE IN BIHAR

Mandal S.S.[1], Singh S.B.[2], Pathak S.K.[3], Singh A.K.[4] and Bhagat R.K.[5]
[1]Bihar Agricultural University, Sabour, Bhagalpur
[2]Regional Maize Research & Seed Production Centre, ICAR-Indian Institute of Maize Research, Begusarai
[3]Department of Agronomy, Bihar Agricultural University, Sabour, Bhagalpur
[4]ICAR-Indian Institute of Maize Research, Ludhiana
[5]Agriculture, Munger commissionaire

Maize is life line of Bihar. The state has deep soil along with plenty of water for irrigation and favorable weather condition for the crop. It is grown all year round like rainy, winter and summer season. The Ganges and its attributes is hub of maize cultivation. Productivity of *rabi* maize in Bihar is the highest in India. There is variable weather condition in the state. In *rabi* season minimum temperature falls upto 1^0 C in the month of January. Whereas, 10 ^{0} C-33 ^{0} C temperature is suitable for vegetative growth, pollen production, fertilization and grain setting. In 2018, winter crop was adversely affected by low temperature. For investigation of non-setting of grain in maize, a detailed survey was done during March and April, 2018. Standing crop of Muzaffarpur, Samastipur, Begusarai, Khagaria, Munger, Bhagalpur, Katihar, Purnea, Araia, Kishanganj, Madhepura, Saharsa and Supoul Districts were observed. Crop was healthy, uniform and vigorous. There was no or less grain in crop sown between mid Octobers to mid November. In these fields there were elongated silk, less tassel branching, mitten ear, high silking anthesis interval, tassel skeletonization, less spikelets, less pollen production, grain on tassel and bareness. Daily mean temperature of October, November and December of the same year was 2^0 C high in comparison to previous year. Up to December crop attained mean temperature between 1200 to 1400 ^{0}C that is required for tasseling. As a result tassel emerged 7 to 10 days earlier. Daily mean temperature of January, 2018 was observed lower (386.45^{0}C) in comparison to 2015 (455.80^{0}C), 2016 (463.75^{0}C) and 2017 (470.45 ^{0}C). In January minimum temperature was less than 10^{0}C and cold prolonged up to 1st week of February that affected pollen production, increased in Anthesis Silking Interval (ASI) and resulted in less fertilization as well as grain setting. To avoid cope of low temperature, recommendation of sowing of crop after mid November will be encountered with westerly wind at milking stage and resulted in more water requirement, higher cost of crop production and low yield. Although, maize cob is enclosed within 6-19 husks where there is air spaces between husks and it is bad conductor of heat. Therefore, cob was least affected by low temperature. Hence, apomictic maize is seems to be option to reduce low temperature risk.

III-2. TEOSINTE ALLELIC INFLUX AS A MEASURE TO ENHANCE AND STRENGTHEN DIVERSITY IN MAIZE

Singh N.K., Adhikari S., Joshi A. and Sahoo S.
Department of Genetics and Plant Breeding
G. B. Pant University of Agriculture and Technology, Pantnagar
narendraksingh2@gmail.com

Being a wild grass in nature, Teosinte has contributed significantly in supporting economy, employment, food and feed requirement of the society across the continents through evolving maize-the highest yielding cereal grain. Domestication followed by artificial selection completely transformed teosinte into a plant architecture morphologically widely divergent from progenitor teosinte. This happened probably because of the selective breeding and artificial selection of few hundred of genes responsive to favourable environmental conditions. Consequently, genetic yield potential of maize has increased tremendously on the one hand but on the other hand consequences of domestication and breeding bottlenecks were realized in the form of limited genetic diversity in cultivated maize when compared with diversity in wild relatives of maize. Recapitulation of allelic diversity, which probably lost during the domestication and selective breeding, through teosinte genomic influx is therefore seems to be essential to ensure sound diverse genetic base for maize improvement programme. Considering preceding facts and prospects in mind, maize inbred line was crossed with teosinte, the resulting F1s were backcrossed with maize followed by four generation of selfing to generate BC1F5 population consisted of 169 lines and were evaluated during *kharif* 2018. Analysis of variance revealed significant differences for all the characters indicating diverse nature of individuals of the BC1F5 population. Days to anthesis, silking and ASI were varied from 47-68, 44-67 and (-) 4-5 days in BC1F5 whereas the same were 52.5, 54.5, 2.5 and 81.5, 78 and (-) 3.0 days in maize and teosinte, respectively. In teosinte and maize height of the plants were 242 and 97.4 cm whereas in BC1F5 lines, it varied from 88-229.3 cm. One to five ears/plant were noted in BC1F5 lines whereas in maize and teosinte, the same was 1 and 242 on average. Ear length and diameter were greatly modified and a range of 3.16-19.16 cm and 0.81-7.16 cm, respectively were observed. Kernel rows/ear and kernels/row were varied from 2.66-16.0 and 3.5 -44.8, respectively. Similarly, for other traits namely flag leaf length, flag leaf width, node bearing first ear, test weight and grain yield/plant, wide range of variations was observed in BC1F5 population. In addition, variations were also observed for anthocyanin colouration of leaf sheath, glumes and anthers, angle between leaves and stem and tassel length. The observations of the investigation therefore indicate diversification of maize germplasm for different characters. Variation for male and female flowering behavior and angle between stem and leaf are seems to be the important allelic introgression and may help in increasing adaptability and productivity of maize. However, introgression of some undesirable features namely loose husk requires strategic intervention to filter out the beneficial alleles from teosinte.

III-3. IDENTIFICATION OF POTENTIAL STABLE LINES AND HYBRIDS WITH LOW PHYTIC ACID AND HIGHER TRYPTOPHAN CONTENT IN MAIZE (*ZEA MAYS*.L)

Lydia P.J.[1], Ravikesavan R.[2], John J.A.[3] and Vinothana N.K.[4]
[1]Center for Plant Breeding and Genetics, Tamil Nadu Agricultural University, Coimbatore
[2,4]Department of Millets, Tamil Nadu Agricultural University, Coimbatore
[3]Tamil Nadu Rice Research Institute, Aduthurai

Maize is an essential cereal crop that serves as a staple crop to meet the dietary and industrial demands of around 60 per cent of the world's population (Shah *et al.*2016). It is known to be rich in essential nutrients like phosphorous, magnesium, calcium, manganese, iron, zinc, calcium and selenium. Although it comprises the needed daily requirements of the protein and micronutrients, there was a constraint in its bioavailability due to the presence of phytic acid and the lack of tryptophan. Maize is a predominant feed in the poultry sector and the absence of tryptophan reduces its protein efficiency and phytic acid hinders the micronutrient absorption by its chelation (Vasal,2000 and Raboy *et al*.2001). Considering the fact to improve both these nutritional factors, an experiment involving forty inbreds, were screened across three locations with twenty morphological and four biochemical traits *viz*., phytic acid, starch, free inorganic phosphorous and tryptophan. Results of AMMI and GGE biplot revealed, four inbreds *viz*., UMI-467, UMI-447, LPA-2-395 and LPA-2-285 with stable lower phytic acid content (2.51-3.47 mg/g) and higher free inorganic phosphorous. Following these inbreds, UMI-158, UMI-1099 and UMI-113 were moderately stable with medium phytic acid levels. Six lines, DMR-QPM-04-05, DMR-QPM-01-06-02, DMR-QPM-03-72, DMR-QPM-06-12, DMR-QPM-09-13-1 and DMR-QPM-11-17 had a higher tryptophan content (0.06-0.09%) across locations. There were perturbations observed in the yield and starch content of the identified *lpa* inbreds, whereas the tryptophan lines were found to be high yielding (Lorenz *et al*.2007 and Naidoo *et al*.2012,). These identified stable donors for low phytic acid and higher tryptophan were further incorporated in a hybrid development program along with three elite ruling inbreds *viz.*, UMI-1200, UMI-1201 and UMI-1205 from the Department of Millets, TNAU. The higher tryptophan and elite inbreds were used as females with stable *lpa* donors as male and hybridization was carried out in a line x tester fashion. The seventy-two hybrids obtained were yet again screened across three locations with two hybrid checks *viz*., CO-6 and CO-H(M)-8 for identifying superior stable *lpa* hybrid with higher tryptophan. Considering the general combining ability, UMI-1200 and UMI-1205 possessed a good *gca* for yield and yield contributing traits across locations. The testers, LPA-2-285, LPA-2-395 and UMI-447 favored the reduction in phytic acid content with a significant negative *gca* for phytic acid. The inbreds DMR-QPM-04-05 and DMR-QPM-01-06-02 lines had exhibited a positive *gca* for tryptophan content across locations. The standard heterosis for phytic acid in comparison to the elite check was observed to be significantly negative for all the hybrids obtained and none of the hybrids surpassed the yield levels of standard checks across locations. This presented influence of reduction in phytic acid in all the resultant hybrids (Raboy *et al*.2001). By AMMI and GGE biplot, UMI-1200 x UMI-467, UMI-1200 x LPA-2-285 and DMR-QPM-11-17 x LPA-2-285 were high yielding with stable low phytic acid and DMR-QPM-09-13-1 x UMI-1099, UMI-1200 x UMI-467 and UMI-1205 x UMI-467 were stable for their yield. The hybrid UMI-1200 x UMI-467 possessed a favorable reduced phytic acid (4.92mg/g) with higher tryptophan (0.07%) content across locations and this hybrid could be studied further to be released as an elite hybrid for its traits of industrial quality.

III-4. EFFECT OF CLIMATE VARIABILITY ON PRODUCTIVITY OF MAIZE IN MAHARASHTRA

Sutar M.W.[1], Karad S.R.[2] and Khot G.G.[3]
Zonal Agricultural Research Station, Sub montane Zone, Shenda Park, Kolhapur

Maize is grown throughout the year i.e. Kharif, Rabi and summer season in India. Maize is the third most important cereal crop in India after rice and wheat. It accounts for 9 per cent of total food grain production in the country. Maize production in India has grown at a CAGR of 5.5 per cent over the last ten years from 14 MnMT in 2004-05 to 23 MnMT in 2013-14. During 2009-10 there was a decline in production primarily due to drought that affected production of kharif crops in the country. Due to climatic variability and dependence of Agriculture on monsoon India's yield at 2.5 MT/hectare is less than half the global average of 5.5 MT/hectare. Productivity of maize (yield) has increased at a CAGR of 2.9 per cent from 1.9 MT/hectare in 2004-05 to 2.5 MT/hectare in 2013-14.Kolhapur district is having highest productivity compared to average productivity of Maharashtra. It was observed that total area under Maize cultivation in Maharashtra is increasing since 2001 (3.26 lakh ha) to 2018 (9.42 lakh ha).Maharashtra has received low rainfall during 2015 (855.7mm) which affected the productivity of Maize crop decreased up to (1554 kg/ha). Since 2001 Maharashtra has got highest productivity (3300 kg/ha) in 2013 due to good amount (1526mm) and well distribution of rainfall throughout the state. Due to climate variability the infestation of Fall Army worm is increasing which affects the yield and productivity of crop throughout the state.

III-5. POTENTIAL OF HIGH AMYLOSE BREEDING TOWARDS IMPARTING FOOD QUALITY AND INDUSTRIAL USES

Arora A.[1], Rakshit S.[2], Das A.K.[2] and Chaudhary D.P.[2]
[1]Department of Plant Breeding and Genetics, Punjab Agricultural University, Ludhiana
[2]ICAR-Indian Institute of Maize Research, Ludhiana
bournville1993@gmail.com

Starch is categorized on the basis of digestibility into two major types, *viz.,* soluble starch and resistant starch. Soluble starch is readily assimilated by the body and quickly elevates blood sugar level leading to high glycemic index (GI). Whereas, the resistant starch, amylose escapes itself from being digested in small intestine and has lower rate of gastric emptying which contributes to lower glycemic index. Amylose starches contribute to lower risk of developing type II diabetes, cardiovascular diseases, colon cancer and obesity. Use of amylose in development of biodegradable thermoplastics has a huge potential to replace the harmful non-biodegradable plastics. Moreover, it is also utilized as an ingredient in gum candies and adhesive for corrugated cardboards. Marker assisted selection (MAS) plays an important role in hastening the breeding process. Development of markers which trace gene responsible for high amylose, *amylose extender1 (ae1)* and markers for several modifiers which are known to increase amylose content up to 70% against normal 25% are a huge milestone. Twenty-six high amylose maize sources and white maize hybrids available at IIMR, Ludhiana are being used for parental diversity and tracking *ae1 gene* (*SbeIIb*) and modifiers (*SbeI*) for foreground selection and whole genome for background selection. The work paves the way for development of white maize with better food quality and industrial use.

III-6. IMPACT OF CLIMATE CHANGE ON PHENOLOGICAL RESPONSES AND PRODUCTIVITY OF MAIZE

Devesh P., Shankar M., Kumar M., Singamsetti A. and Singh R.
Department of Genetics and Plant Breeding, Institute of Agricultural Sciences,

Banaras Hindu University, Varanasi
pavan.devesh04@bhu.ac.in

Changing global climatic conditions critically affect the growth and productivity of maize. Maize is no exception and to safeguard a future supply we must initiate to understand how climate influences both phenological development and productivity of maize. Temperature and precipitation are the two climatic factors that will have a significant advantage in maize phenology and profitability. The warming climate will accelerate the phenological improvement in light of the fact that the quantity of thermal units required for leaf appearance is generally consistent in the vegetative stage. The efficiency of maize is diminished when unusual temperature occurrences during pollination and are additionally distorted when there are water shortages at pollination. During the kernel-filling period, warm temperatures over the upper limit cause a decrease in yield. Model evaluations recommend that for each 1°C increment in temperature there is almost a 10% yield decrease. To satisfy world needs, new adjustment rehearses are expected to give water to the developing harvest and stay away from outrageous temperatures during the growing season. Environmental change will keep on influencing maize creation and understanding these impacts will help figure out where future generation zones exist and inventive adjustment practices to profit yield strength could be used. The necessity to study phenological responses of maize to changing climatic conditions is therefore important to conserve maize productivity.

III-7. EVALUATION OF QUALITY PROTEIN MAIZE HYBRIDS SUITABLE FOR SOUTHERN KARNATAKA

Mahadevu P., Shobha D., Mallikarjuna N., Jadesha G., Ravindrababu B.T., Shivakumar B.S. and Swapna G.
AICRP on Maize, Zonal Agricultural Research Station, V.C. Farm, Mandya

Maize is an important multipurpose crop grown for food, feed, fodder, culinary and industrial purpose in fulfilling food and nutritional needs of both human and livestock. Recently developed QPM hybrids play an important role in terms of fulfilling the micronutrients through bio-fortified maize and concentrated feeds. We evaluated different QPM hybrids during Kharif season at Zonal Agricultural Research Station, V.C.Farm, Mandya during 2015-16 to 2018-19. Among the HQPM hybrids evaluated, HQPM-7 recorded highest mean grain yield of 9034 kg/ha as compared to other HQPM hybrids and also normal grain hybrids HEMA (8533 kg/ha) and MAH-14-5 (8396 kg/ha). Similarly is the hybrid HQPM 7 also recorded higher grain yield of 9595 kg/ha as compare to other hybrids during year 2017-18 at Mandya. These hybrids are found promising as a source of nutrient enriched maize based food and feed for achieving nutritional security for both human and livestock in the country.

III-8. Supercharging Crops for addressing climate change

Gagan Jeet, Kaur S., Bhushan B, Singh A. and Rakshit S.
Punjab Agricultural University, Ludhiana
ICAR – Indian Institute of Maize Research, Ludhiana
alla.singh@icar.gov.in

Increasing carbon dioxide (CO_2) emissions and the rise in global warming have sensitized people world-over to design new ways to tackle this universal problem. Amongst the many endeavours, the idea of addressing climate change by enabling crops to absorb more CO_2 is gathering attention. Agriculture, itself is a big driver of climate change due to its use of fossil fuels in farm mechanization. However, the photosynthetic capability of crops, if enhanced, can allow plants to take up more CO_2, and delay the rise in global temperatures. Annually, plants absorb a net of about 19 gigatons of CO_2, while about 37 gigatons is released in the environment due to human activity. Engineering plants to absorb more CO_2 would result in annual decrement in the global temperature gradient. Maize, being an important cereal crop, can be potentially deployed for mitigation of temperature rise, along with other crops. The recent understanding of the CO_2 absorption in plants and plant engineering to increase photosynthetic activity are discussed.

III-9. CLIMATE-RESILIENT MAIZE VARIETIES PRODUCTION AND DEPLOYMENTS IN FARMING SYSTEM: TODAY'S NEED TO COMBAT THE EFFECT OF CLIMATE CHANGE IN THE DEVELOPING WORLD

Choudhary J.R., Choudhary M.[2], Tripathi A.[3] and Aggarwal S.K.[2]
[1]ASCO, Rajasthan State Seed and Organic Certification Agency, Jaipur
[2]Indian Institute of Maize Research, Ludhiana
[3]Govind Ballabh Pant University of Agriculture and Technology, Pantnagar

Most of the corn in developing world is grown as a rain-fed crop that is prone to the vagaries of seasonal monsoon rains and that severely affect the corn yields. The uneven distribution of monsoon rains leads to drought or water logging at different stages of crop growth, which is the key factor responsible for low productivity in rain-fed maize. Because of the risk for uncertain economic returns, farmers often hesitate to invest in improved seeds, fertilizers, and inputs, which further increase the poor yield of rain-fed maize. The effects of climate change are further threatened by the already complex mega-environment of maize in the Asian tropics, identified as climate-sensitive, with high vulnerability and low capacity for acceptance. Smallholders still rely mainly on open pollinated varieties (OPV) or obsolete hybrids created 30 years ago, which limits their ability to provide food and nutrition security. Climate-resistant corn has been specially developed to increase tolerance to characteristics associated with a variable and changing climate, along with the yield potential of crops, protective qualities and consumer preferences. More evidence is emerging that confirms the benefits of climate-resistant maize for increasing yields, reducing crop yield variability, and ultimately improving food security. To Increase genetic benefits of maize in the tropics of stress, as well as increase the speed, accuracy and efficiency of reproductive progress, the rational and effective integration of modern tools / strategies, in particular a high density of genotyping, a high productivity and precise phenotyping, DH technology, Molecular marker assisted selection and genomic selection based breeding are essential. New developing seed enterprises in the developing world also need to be strengthened to become more market-oriented and dynamic in order to provide smallholders with greater access to affordable and climate-resistant improved seeds.

Theme-IV

Best production Practices – Maize and Maize Based Systems

IV-1. ECOLOGICAL INTENSIFICATION A STEP AHEAD FOR CLIMATE RESILIENT MAIZE BASED CROPPING SYSTEMS

Singh N., Yadav D.B., Kamboj M.C. and Sharma P.
Chaudhary Charan Singh Haryana Agricultural University, Regional Research Station, Karnal
narendersingh.bagri@gmail.com

Maize is the third most important cereal crop in India after rice and wheat. The diversified use of this crop is gaining demand as grain, animal feed and other industrial uses. For food security pressure is there on policy maker, scientist and farmers to increase the yield of maize crop. Strategies to address future global food security thus require innovation to increase agricultural production in a sustainable, affordable way in the poorest regions of the Indiaand to reduce the environmental impact of agriculture and its dependence on non-renewable resources. Ecological intensification, the smart use of biodiversity-mediated ecosystem functions to support agricultural production, is portrayed as the most promising avenue to achieve these goals. For this an experiment on Ecological intensification with maize- wheat – moong cropping system was conducted in *kharif* 2017 at CCS Haryana Agriculture University, Regional Research Station, Karnal. The layout of the experiment in RBD design with three replication with eight treatments: T1-Farmer practice, T2-Ecological Intensification (EI), T3- EI minus tillage practice (Conventional tillage without residue retention in all crops), T4 - EI minus Nutrient management (Absolute control for nutrients in all crops), T5 - EI minus Planting density (Farmer adopted genotype and density in all crops), T6 - EI minus Water management (Complete rainfed for maize and farmers practice for rest of the crops), T7 - EI minus Weed management (No weed management in all crops) and T8 - EI minus Disease and insect management (No management in all crops). In *kharif* 2017 in maize crop treatment T2 gave significantly higher grain yield (70.8 q/ha) which was at par with treatment T3 (70.7 q/ha) as compared to all the treatments. Minimum grain yield was observed in treatment T7 (15.0 q/ha) and T4 (35.0 q/ha). In wheat crop maximum grain yield (71.3 q/ha) was observed in treatment T2 (71.3 q/ha) which was at pat with T1 (71.0 q/ha), T3 (68.1 q/ha), T5 (70.5 q/ha), T7 (67.2 q/ha) and T8 (70.3 q/ha). Minimum grain yield was observed in T4 (45.0 q/ha) and T6 (48.2 q/ha). In both the crops Ecological intensification performs best and maximum yield was recorded.

IV-2. MAIZE BASED SYSTEM WITH PRECISION CONSERVATION AGRICULTURE: A SUITABLE ALTERNATIVE TO RICE-WHEAT ROTATION IN INDO-GANGETIC PLAINS OF INDIA

Singh A.K.[1], Jat S.L.[1], Parihar C.M.[2], Mahala D.M.[1], Bamboriya S.D.[1] and Ritesh[1]
[1]ICAR- Indian Institute of Maize Research, Ludhiana
[2]ICAR-Indian Agricultural Research Institute, New Delhi

Rice-wheat (RW) cropping system in north-west India, although providing food security in the country, have led to soil degradation and over exploitation of underground water resources (Hobbs and Gupta, 2004; Sharma *et al.*, 2012). Furthermore, conventional crop management practices for RW system entail high production costs and are highly inefficient in the use of inputs. The diversification of

RW systems with maize-based systems and alternate soil and crop management practices could help enhance the system productivity, sustain soil health and environmental qualityand save irrigation water and labour costs, provide palatable fodder and meet increased demand of maize grains from piggery and poultry industries (Singh *et al.*, 2016).

Maize, an important crop for food and nutritional security as maize grain is mainly used for feed (63%), food (23%) and industrial purpose (13%) in the country (Yadav *et al*., 2014). In the past, maize was evaluated as an alternate crop to rice with conventional management practices in RW system, but it was not proved economical due to its lower yield and market price. However, in recent years with the introduction of single cross high yielding maize hybrids and mechanized maize cultivation with availability of good postemergence herbicides provided options for crop diversification in RW systems.In the north-western Indo-Gangetic plains (IGP) maize is commonly grown in rotation with wheat. Integration of short-duration legumes (e.g. mungbean) in cropping system improves the soil health and increase farmer's profit in a cereal-based cropping systems (Parihar *et al*. 2016a). Hence, an experiment was initiated at ICAR-IIMR, Ludhianato compare the performance of the rice-wheat-moongbean(RWMb)with maize-wheat-moongbean(MWMb)systemunder conventional and conservation agriculture practices. In comparison to RWMb system, the system productivity was 33% (15% in 2017-18) and 25% (11% in 2017-18) higher in conservation and conventional tillage basedMWMb system, respectively in the 2nd year. The B:C ratio were also highest in conservation MWMb system (2.67 and 3.35) followedbyconventionalMWMb system (2.03 and 2.75) and least inconventional RWMbsystem (1.88 and 2.24). Further, the MWMb system was also water-use efficient as it reduced water consumption by 82.8 % as compared to rice-wheat system. Hence,MWMb system can be grown 5-6 times, with the same amount of waterused to grow one cycle of rice-wheat system. So, replacement of RWMb system with MWMb system increased system productivity (up to 33%), profitability (up to 50 %) and also resulted in huge (82 %) water saving.Therefore, the maize-wheat-mungbean system with conservation followed by conventional practices offers suitable alternative to the conventional rice-wheat system for saving of wateralong with enhancing productivity and profitability to ensure sustainability of agriculture in North-Western plain zone and similar agroecologies.

IV-3. BACTERIAL DIVERSITY ANALYSIS OF RICE-WHEAT AND MAIZE-WHEAT CROPPING SYSTEMS

Verma D.[1], Mahala D.M.[1], Bhar F.A.[2], Singh A.K.[1], Singh A.[1]
[1]ICAR-Indian Institute of Maize Research, Ludhiana
[2]Shere-Kashmir University of Agricultural Sciences and Technology, Srinagar

Conventional tillage (CT) practices in rice-wheat and maize-wheat cropping system is adversely affecting bulk densities of soil aggregates. Conservation agriculture (CA) is a step towards preserving soil from disturbance and promoting low-input agriculture. In order to understand the impact of management practices on the bacterial diversity in the fields, soil samples were taken from different fields, *viz.*, 4 from rice-wheat cropping systems, 4 from conventional tillage maize-wheat cropping systems and 4 from conservation agriculture maize-wheat cropping systems. The fields have been under the same cropping pattern for the third year, as of now. The different cropping systems were fertilized according to 4 different schemes, *viz.*, Farmer Filed Practices

(FFP), Recommended Dose of Fertilization (RDF), Green Seeker-based application (GS) and Site-specific nutrient management (SSNM). Serial dilution method was used to identify the microbial population present in all the cropping systems. Chromogenic agar medium was used for the isolation and differentiation of bacterial profiles in soil. Results were observed after the incubation period of 24 hours at 37° C. The typing of bacterial diversity provides a way to understand the role of micronutrient application on soil flora as well as provides a means to monitor field performance after successive years of a particular management practice.

IV-4. WEED SEED BANK STUDIES UNDER DIFFERENT CROPPING SYSTEMS OF INDO-GANGETIC PLAINS

Bahar F.A.[1], Singh A. K.[2], Jath S. L.[2], Parihar C.M.[3], Mahala D.M.[2], Bamboriya S.D.[2] and Ritesh[2]
[1]Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir
[2]ICAR-Indian Institute of Maize Research, Ludhiana
[3]ICAR-Indian Agricultural Research Institute, New Delhi

Weed infestations are the major constraints and its control is a major hurdle in conservation agriculture (CA) based systems since weed ecology and management are entirely different in CA systems. Weeds pose serious threat to the companion crop through its competition for nutrients, water, sunlight and space, which cause considerable reduction in yield. The sources of these huge economic losses and weed infestations in crops is primarily due to weed seed bank (WSB) which describes the reservoir of viable weed seeds or fruits found in soil or at its surface. To deplete the weed seed bank, weed seed-set should be avoided by all means and needs to be addressed in a holistic way. Keeping in view the above facts, the present investigation was undertaken to study the "weed seed bank studies under different cropping systems of indo-gangetic plains" at ICAR-Indian Institute of Maize Research, Ludhiana, Punjab. During the course of study it was observed that lower weed density (No./8 kg soil) of 88.67 and 118.33 was observed in Rice-Wheat-Moong system (conventional agriculture) at both 0-5 cm and 5-15 cm soil depths. At 5-15 cm soil depths, Maize-Wheat-Moong in both the systems (conventional and conservation agriculture) recorded more number of weeds than Rice-Wheat-Moong system (conventional agriculture). Weed density (No./8 kg soil) was highest at 0-5 cm soil depth in conservation agriculture than 0-5 cm in conventional agriculture. Highest total and average weed density (No./8 kg soil) of 508.33, 254.16 was observed in Maize-Wheat-Moong system (conservation agriculture) followed by 433.33, 216.66 and 207, 103.5 in Maize-Wheat-Moong system (conventional agriculture) and Rice-Wheat-Moong system (conventional agriculture) respectively. Therefore it can be concluded that weed seeds and weed growth is highest in conservation agriculture than conventional agriculture and needs more focus for weed management for increasing productivity and profitability of cropping systems in Indo-Gangetic plains of India.

IV-5. EFFECT OF VARIED ESTABLISHMENT METHODS VIS-A-VIS NUTRIENT MANAGEMENT ON PRODUCTIVITY OF MAIZE IN BIHAR

Kumar M.[1], Kumar A.[2], Pramanick B.[1], Alam T.[3] and Chand P.[4]

[1]Department of Agronomy, Dr. Rajendra Prasad Central Agricultural University, Samastipur
[2]Department Plant Breeding and Genetics, [3]Department of Entomology, [4]Department of Plant Pathology, Tirhut College of Agriculture, Dholi, Muzaffarpur
biswajit@rpcau.ac.in

Maize (*Zea mays* L.) together with rice and wheat provides at least 30% of the food calories to more than 4.5 billion people in 94 developing countries. Maize is a versatile crop having wider adaptability and particularly important to the poor people for overcoming hunger and improving food security not only in India but also in other parts of the World. For increasing its productivity, better nutrient management systems coupled with suitable establishment method are needed to complement genetic improvement efforts. This present experiment was conducted during *rabi* season of 2017-18 at research farm of TCA, Dholi. The experiment was carried out in a split plot design with 3 replications. Different establishment methods such as permanent bed, zero tillage and conventional tillage were laid in main plot and varied nutrient management options viz. RDF, SSNM, FFP were there in sub plot. Total treatment combinations were nine. The maximum amount of cob as well as grain yield of maize was found in permanent bed managed with SSNM, while, the lowest values of grain yield was attained in zero tillage managed with FFP. Both the permanent bed and SSNM depicted significantly higher grain yield values being 9.29 and 9.07 Mg ha^{-1}, respectively. Better yield under the permanent bed might be attributed to better establishment of the crop as well as adequate moisture supply escaping water logging. Under SSNM, proper demand of the nutrient for better crop growth was met up and it was ultimately reflected through superior yield. So, it can be concluded that permanent bed along with SSNM would be the best option to the farmers of Bihar to get higher productivity of *rabi*-maize.

IV-6. RESPONSE OF SWEET CORN HYBRIDS TO CROP ESTABLISHMENT METHODS AND FERTILITY LEVELS UNDER TEMPERATE CONDITIONS

Hussain A.[1], Dar Z. A.[2], Ganai M.A.[1], Jehangir I.A.[1], Shikari A.B., Najeeb S.[1], Teeli N.A. and Bhat N.A.[1]
Mountain Research Centre for Field Crops, Khudwani, Anantnag
[2]Dryland Agriculture Research Station, Budgam
Shere-Kashmir University of Agricultural Sciences and Technology of Kashmir

The awareness about sweet corn in Kashmir valley is growing gradually and may further increase with the growth in tourism industry. Direct seeding results in poor crop stand due poor germination and cutworm damage especially during early sowing. Therefore a field investigation effect of sweet corn hybrids, crop establishment methods and fertility levels on yield and profitability was conducted during the year *kharief* 2018 at Mountain Research Centre For Field Crops (SKUAST-K), Khudwani, Anantnag. A field experiment was conducted on sweet corn Hybrids and crop establishment methods under varied fertility at Mountain Research Centre for Field Crops, Khudwani, Anantnag. The treatments comprised of two hybrids viz Mithaas and Sugar-75, two crop establishment methods viz direct seeding, transplanting evaluated under four fertility levels viz 90:30:15, 120:45:30, 150:60:45of N:P2O5:

K2O kg/ha and 10 t FYM/ha+150:60:45 of N:P2O5:K2O kg/ha. Soil medium was prepared by thoroughly mixing soil: sand: manure in the ratio of 2:1:1.A poly bag of 300 g capacity was filled with this mixtures. Further a 110:54:40 mg $N:P_2O_5:K_2O_5$/kg soil was also added to the potting mixture. A single seed was placed in each poly bag and same was watered with a rose cane. On the same day the seed of two hybrids was sown in direct seeded treatments. Twenty two (double the required plant population) were sown in each row. The poly bag was tared without disturbing the lump of soil holding the root zone. Crop establishment methods had a non significant effect but higher fertility levels resulted in significant increase in plant height. However, plant population was far higher in transplanting method. Transplanting method resulted in almost 50% increase in plant population that contributed to higher green cob and stover yield. Direct seeding resulted in significantly higher no. of cobs/plant and similarly higher fertility level of 150:60:45 10 t FYM+150:60:45), resulted in higher no of cobs/plant. Mithas hybrid recorded higher no. of grains/cob. Among the crop establishment methods direct seeding resulted in higher no of grains/cob because of sparse plant population. Fertility levels also resulted in a significant increase in no. of grains /plant upto highest fertility level of 10 t FYM+150:60:4510 t FYM+150:60:45. With regard green cob yield with and without husk, Mithas hybrid yielded higher by 13% and 14.7 %, respectively. Transplanting method resulted in 29 and 32% increase in green cob yield with and without husk, respectively. With the increase in fertility levels from F1 to F4, the increase in green cob yield without husk was to the extent of 16, 24, 30% respectively over F1.The corresponding figures for the green cob yield with husk were 23, 36 and 48% respectively. Higher green stover yield to the extent of 12, 17 and 24 % was recorded at F2, F3 and F4 over F1, respectively was recorded, because increased and consequent uptake of nutrients. A net profit of Rs 411804 and Rs 351724 and B:C ratio of 4.48 and 3.83 was realized in Mithas and Sugar-75. Transplanting registered 26 % higher net profit.

IV-7. PERFORMANCE OF SWEET CORN (*ZEA MAYS* L. SSP *SACCHARATA*) UNDER VARYING PLANT DENSITIES AND FERTILITY LEVELS

Singh D., Chouhan D. and Parik N.
Maharana Pratap University of Agriculture and Technology, Udaipur

The field experiment was conducted during *Kharif* 2018 at Instructional Farm, Rajasthan College of Agriculture, MPUAT, Udaipur on clay loam soils having medium fertility status (285.6 kg N, 21.6 kg P_2O_5 and 301.6 kg K_2O ha^{-1}).The objectives of experimentation were to standardize economically viable plant density and fertility level for sweet corn. The treatment consisted combinations of four plant densities (55,555, 66,666, 83,333 and 1,11,111 plants ha^{-1}) and four fertility levels (80 kg N + 30 kg P_2O_5 + 20 kg K_2O, 110 kg N + 40 kg P_2O_5 + 30 kg K_2O, 120 kg N + 50 kg P_2O_5 + 40 kg K_2O and 140 kg N + 60 kg P_2O_5 + 50 kg K_2O ha^{-1}). These 16 treatments combinations were evaluated under factorial RBD with three replications.The results of present experiment revealed that advancing plant densities from 55,555 to 1,11,111 significantly increased plant plant population at successive stages. Increasing plant density from 55,555 to 66,666 plants ha^{-1} failed to record significant variation in plant height, however, further increase in plant densities significantly increased plant height at successive stages. Days to 50 per cent tasseling and silking failed to record perceptible variation under increasing plant densities. The maximum dry matter $plant^{-1}$ and LAI were recorded under 55,555 plant ha^{-1}.

Advancing plant density from 55,555 to 1,11,111 plants ha^{-1} decreased dry matter plant^{-1} and LAI at successive stages. Increasing plant densities from 55,555 to 1,11,111 plants ha^{-1} significantly increased the crop growth rate between 45-60 DAS and 60 DAS to harvest of crop. However, increasing densities failed to record perceptible variation in RGR at early duration. The cob plant^{-1} and grain rows cob^{-1} did not influenced under varying plant densities. Advancing plant densities from 55,555 to 1,11,111 plants ha^{-1} significantly increased green cobs, fodder and biological yield. However, the green cobs yield recorded 83,333 to 1,11,111 was statistically at par. The maximum nutrient content and minimum uptake were recorded under 55,555 plants ha^{-1}. Advancing plant densities from 55,555 to 1,11,111 plants ha^{-1} decreased nutrient content in grain and stover, however, improved uptake of nutrient by grain, stover as well as total uptake. Advancing plant density from 55,555 to 1,11,111 plants ha^{-1} increased PFSR incidence on sweet corn crop. Maintaining 66,666 plants ha^{-1} recorded significantly higher B C ratio over 55,555 plants ha^{-1} and proved economically profitable compared to rest of densities Increasing fertility level significantly enhanced plant height, dry matter and LAI at successive stages and CGR at initial and at later durations. At the same time increasing fertility levels significantly reduce days to 50 per cent tasseling, silking, plant population and RGR at both the durations. Advancing fertility levels from 80 kg N + 30 kg P_2O_5 + 20 kg K_2O ha^{-1} to 140 kg N + 60 kg P_2O_5 + 50 kg K_2O ha^{-1} increase various yield attributing parameters consequently green cobs, green fodder and biological yield significantly. However, cobs plant^{-1}, grains cob^{-1} and grain row cob^{-1} did not vary significantly under increasing fertility levels. Increasing fertility levels from 80 kg N + 30 kg P_2O_5 + 20 kg K_2O ha^{-1} to 140 kg N + 60 kg P_2O_5 + 50 kg K_2O ha^{-1} brought about significant increase in nitrogen, phosphorus and potassium content and uptake of the sweet corn grain and stover at varying extents. There was no significant variation in the TSS content of grain. However, the protein content increases with increasing fertility levels. Application of 110 kg N + 40 kg P_2O_5 + 30 kg K_2O ha^{-1} significantly increased net return and B C ratio and proved economically beneficial over 80 kg N + 30 kg P_2O_5 + 20 kg K_2O ha^{-1}.

IV-8. RESPONSE OF GROWTH, YIELD AND YIELD ATTRIBUTES OF POPCORN (*ZEA MAYS* EVERTA) TO ORGANIC AND INORGANIC SOURCES OF NUTRIENTS

Rashid Z., Iqbal S., Kanth R.H., Dar Z. A., Rakshanda A., Mehfuza H., Sabina N., Saleem K., Sabiya, Seerat, Shabina M. and Faisal
Faculty of Agriculture, Division of Agronomy, Wadura Campus,
Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir

In order to study the effect of different organic and inorganic sources of nutrients on growth, yield and yield attributes of popcorn, an experiment was conducted at crop research farm of Division of Agronomy, Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Wadura during *kharif* 2017. The results indicated that the application of RDF ($N_{120}P_{60}K_{40}$) kg ha^{-1} recorded highest growth and yield parameters viz. plant height (187.58 cm), number of functional leaves (12.05), leaf area index (6.68), dry matter accumulation (139.9 q ha^{-1}), yield attributes {number of grains per cob (480.0) and 1000 grain weight (193g)}, grain yield (38.8 q ha^{-1}), stover yield (110.2 q ha$^{-1)}$ and benefit :cost ratio but was at par with 75% RDF + FYM @ 10 ha^{-1} + AZO + PSB + KSB (T_7) while significantly lowest value of above mentioned parameters was found in control (T_1). No significant differences were found in rest of the treatments. So, it was considered that application of 75% RDF + FYM @ 10 t ha^{-1} + AZO + PSB + KSB over RDF should be recommended because of its considerable influence on improving soil health and maintaining ecological balance and also with better net and gross returns.

IV-9. INFLUENCE OF ORGANIC AND INORGANIC SOURCES OF NUTRIENTS ON SOIL HEALTH AND QUALITY PARAMETERS OF POP CORN

Iqbal S., Rashid Z., Kanth R.H., Dar Z.A., Aiyman, Shaista, Mehfuza, Sabina N., Seerat, Shabina, Sabiya, Saleem K., Rakshanda and Bhat R.A.
Faculty of Agriculture, Division of Agronomy, Wadura Campus
Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir

The field experiment was conducted at crop research farm of Division of Agronomy, Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Wadura during *kharif* 2017. The experiment was laid in RCBD having twelve treatments and three replications. The treatments where T_1(Control),T_2 (RDF) (120:60:40 kg N, P_2O_5 and K_2O ha^{-1} respectively), T_3 (FYM @ 15t ha^{-1}), T_4 (Vermi-compost @ 5t ha^{-1}),T_5 (Poultry manure @ 5t ha^{-1}), T_6 (75% RDF + FYM @ 10t ha^{-1}), T_7 (75% RDF + FYM @ 10t ha^{-1} + *Azospirillum* + PSB + KSB) T_8 (FYM @ 10t ha^{-1} + *Azospirillum*), T_9 (FYM @ 10t ha^{-1} + *Azospirillum* + PSB), T_{10} (FYM @ 10t ha^{-1} + *Azospirillum* + PSB + KSB), T_{11} (Vermi-compost @ 5t ha^{-1} + *Azospirillum* + PSB + KSB) , T_{12} (Poultry manure @ 5t ha^{-1} + *Azospirillum* + PSB + KSB).The results of the study showed that the treatment (T_2) recorded highest quality parameters viz. popping percentage (83.5%), popping expansion volume (13.2 ml), flake size (2.7 cm), protein content (8.8%), total nitrogen, phosphorous and potassium uptake were (127.44, 36.72 and 159.33 kg ha^{-1}), respectively but was at par with 75% RDF + FYM @ 10t ha^{-1} + AZO + PSB + KSB (T_7) while significantly lowest quality parameters viz. popping percentage (73.1%), popping expansion volume (11.6 ml), flake size (1.8 cm), Protein content, total nitrogen, phosphorous and potassium uptake were 49.80, 12.86 and 69.118) kg ha^{-1}, respectively were recorded for the treatment (T_1).

IV-10. EFFECT OF PLANTING DENSITY AND NUTRIENT MANAGEMENT PRACTICES ON THE YIELD OF MAIZE HYBRIDS IN KASHMIR

Ayman[1], Alie B.A.[2], Singh P.[3], Kanth R.H.[1], Dar Z.A.[4], Sadaf[1], Shayista[1], Shayan[1] and Saima[5]
[1] Division of Agronomy, FOA/ RRS, Wadura
[2]Saffron research station, Konnibal, Pampore
[3]Krishi Vigyan Kendra , Shopian
[4]Dry Land Agricultural Research Station, Srinagar
[5]Division of Basic Sciences & Humanities, FOA /RRS, Wadura
Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir
aymanazad07@gmail.com

The field experiment entitled "Planting density and nutrient management effects on yield of maize hybrids in temperate ecology of Kashmir" was carried out at Dryland

(Karewa) Agriculture Research Station, SKUAST-K, Budgam during the Kharif season 2017. The experiment comprised of three factors with two maize hybrids viz. Kanchan-101 and Bio-605 as main-plot treatments and two plant geometries viz. 60 cm×20 cm (83,000 plants ha^{-1}), 60 cm×15 cm (1, 11,111 plants ha^{-1}) and three nutrient management practices viz. RDF (Recommended Dose of Fertilizers), SSNM (Site-Specific Nutrient Management) and FP (Farmers Practice) as sub-plot treatments replicated thrice. The results of the experiment revealed that among maize hybrids Bio-605 recorded significantly higher values of yield parameters like grain row cob^{-1}, grains row^{-1} and grains cob^{-1}, thus, higher grain yield (8.36 t ha^{-1}). The highest cobs plant^{-1}, grain rows cob^{-1}, grains row^{-1}, grains cob^{-1}, grain yield (8.16 t ha^{-1}) and harvest index (29.3 %) was found higher with plant population of 83,000 plants ha^{-1}. Application of SSNM improved yield attributes (cob length, grain rows cob^{-1}, grains row^{-1}) consequently grain yield (8.70 t ha^{-1}), stover yield (19.24 t ha^{-1}) and harvest index (31.9 %). Nitrogen, phosphorous and potassium uptake were found maximum under plant population of 1, 11,111 plants ha^{-1} with SSNM nutrient management practice .From present study it can be concluded that maize hybrid Bio-605 under 60 cm×20 cm spacing (83,000 plants ha^{-1}) with SSNM found better suited for temperate conditions of Kashmir as it gave the higher gross profit (₹164770 ha^{-1}), net return (₹111759ha^{-1}) and B:C ratio (2.11).

IV-11. ECOLOGICAL INTENSIFICATION FOR CLIMATE RESILIENT MAIZE BASED CROPPING SYSTEMS IN NEW ALLUVIAL ZONE OF WEST BENGAL

Biswas S.[1], Debnath S.[2] and Saha A.[3]
[1,2]AICRP on Maize, Directorate of Research, Bidhan Chandra Krishi Viswavidyalaya, Kalyani
[3]College of Agriculture, Lembucherra, West Tripura
abhijitsaha80@gmail.com

Ecological intensification is the process of improving both yields and environmental performance of crop production with a focus on precise management of all production factors and maintenance or improvement of soil quality. An experiment was conducted at District Seed farm, Kalyani, Nadia, Bidhan Chandra Krishi Viswavidyalaya, West Bengal during *kharif* 2017 with the objective to develop the best crop management practices by enhancing the ecological processes and buffering the risk against the climatic aberrations for enhancing the resource use efficiency and soil health. The soil of the experimental field was alluvial having sandy clay loam in texture, pH neutral in reaction (7.2) and medium in organic carbon content (0.54 %). The experiment was laid out in randomized block design with twelve treatments [T1: Farmer practice, T2: Ecological intensification (EI), T3: EI minus tillage practice (Farmer adopted tillage and residue management in all crops), T4: EI minus Nutrient management (Farmer adopted nutrients in all crops), T5: EI minus Planting density (Farmer adopted genotype and density in all crops), T6: EI minus Water management (Complete rainfed for maize and farmers practice for rest of the crops), T7: EI minus Weed management (Farmer adopted weed management in all crops) and T8: EI minus Disease and insect management (Farmer adopted management in all crops)] and replicated three times. The experimental results revealed that ecological intensification (EI) recorded maximum grain yield (10,211 kg ha^{-1}), stover yield (12,243 kg ha^{-1}), plant height (274.4 cm), 100 seed weight (46.0 g), net return (RS.

90,022 ha^{-1}) and B: C ratio (2.6) of maize. Among the treatments T4 i.e nutrient management played significant role in maximum yield reduction both grain (5988 kg ha^{-1}) and stover (7778 kg ha^{-1}) which also produced lowest plant height (241.8 cm), 100 seed weight (36.0 g), net return (Rs. 35,416 ha^{-1}) and B: C ratio (1.7) of maize. It was found that maximum uptake of nutrients (231.9 kg N ha^{-1} , 61.0 kg P ha^{-1} and 230.7 kg K ha^{-1}) by crop were recorded in EI treatment with maximum organic carbon content. Therefore, from the experiment it can be concluded that Ecological intensification (EI) in maize is an option for achieving higher yield, economic benefit and also leads to increase nutrient supply capacity of soil, input use efficiencies and soil health.

IV-12. MAIZE-LEGUME INTERCROPPING SYSTEM FOR ENHANCING THE PRODUCTIVITY AND SUSTAINABILITY OF AGRICULTURAL PRODUCTION

Rasool F., Nasseer S, Hakeem S.A., Majid S., Bashir S., Rashid Z., Nisa S., Dar Z.A. and Habib M.
AICRP on Maize-Srinagar Centre
Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir

The study was conducted at Dryland Agriculture Research Station (DARS), Srinagar during *Kharif,* 2019 to enhance the production and productivity of the intercropping system. As the availability of land for agriculture is shrinking every day and is increasingly utilized for non-agricultural purposes. Under this situation, one of the most important strategies to increase the agriculture output is the development of high intensity cropping system. Among different treatments, Maize (60 cm) and common bean grown under 1:1 ratio showed better results compared to maize plus bean in a paired row arrangement. The intercropping system was evaluated interms of crop yields and growth. The Land equivalent ratio (LER) for yield and growth was 1.12 and 1.25 respectively showing yield and growth advantage of intercropping system. Maize equivalent yield (MEY) was also highest for most of the intercropping treatments relative to sole-crop maize with yield advantage of 14% from single row IPA (inter-planting arrangement). Also financial returns showed increase by 16% relative to sole crop maize.
Key words: Intercropping, LER,MEY, Zea mays

IV-13. RESPONSE OF SWEET CORN (*ZEA MAYS* L. VAR. *SACCHARATA*) TO SOWING DATES AND DIFFERED MULCHING IN SPRING SEASON

Bhatnagar A. and Dehury S.
Department of Agronomy, G.B. Pant University of Agriculture and Technology, Pantnagar

Field experiment was conducted at N.E.B. Crop Research Centre, G.B. Pant University of Agriculture and Technology, Pantnagar during spring season 2016 to study the effect of different sowing dates and time of application of rice straw mulch @5t/ha on growth, yield and economics of sweet corn (*Zea mays* L. var. *saccharata*). The soil of experiment plots was sandy loam in texture with neutral in reaction, organic carbon (0.65%), available nitrogen (289 kg/ha) and available phosphorus (29.1 kg/ha) and available potassium (245.3 kg/ha). The experiment consisted of 12

treatments; having 4 sowing dates (8^{th}, 18^{th}, 28^{th} February and 10^{th} March) and 3 time of mulch application (no mulch, mulch application after 2^{nd} and 3^{rd} irrigation) was laid out in Split Plot Design with three replications. Sowing dates were accommodated in main plots and mulch treatments in sub plots. The growth, yield attributes, husked cob yield, dehusked cob yield, biological yield, TSS in grains and economics were influenced significantly by sowing dates. Crop sown on 8^{th} February being at par with 18^{th} February resulted in significantly more husked cob yield (15870 kg/ha), dehusked cob yield (11427 kg/ha) and total soluble solids (15.59 brix) than that of other sowing dates. The maximum gross return (Rs. 171406/ha), net return (Rs. 110361 /ha) and B:C (1.80) were obtained under 8^{th} February which was at par with 18^{th} February but significantly superior to rest of sowing dates. Application of rice straw mulch after 2^{nd} irrigation being at par with mulch application after 3^{rd} irrigation resulted into better growth and produced significantly more husked cob yield (15497 kg/ha) and dehusked cob yield (11128 kg/ha) than without mulch. TSS in grain was not affected significantly by mulch application. The maximum gross return (Rs. 166932/ha), net return (Rs. 105337/ha) and B:C (1.71) were recorded under mulch application after 2^{nd} irrigation that was significantly higher than without mulch but remained statistically same with mulch application after 3^{rd} irrigation. From present study it can be inferred that, during spring season in north western plains of India, sweet corn should be sown from 2nd to 3rd week of February. Application of rice straw mulch @ 5 t/ha after 2nd irrigation is effective in increasing growth and productivity with higher economic returns.

IV-14. RESPONSE OF MAIZE TO FOLIAR AND SOIL APPLICATION OF ZINC

Gajbhiye P.N., Karad S.R. and Khot G.G.
Zonal Agricultural Research Station, Shenda Park, Kolhapur
AICRP on Maize, Kolhapur
npraving@rediffmail.com

Zinc deficiency in soil is induced due to soil micronutrient depletion from intensification of cultivation, application of high analysis NPK fertilizers and lesser use of organic manure. Among the various growth factors, zinc was recognized as one of the main limiting factors of maize crop growth and yields. This hypothesis was verified by conducting an experiment on zinc deficient soil to study the response of applied zinc through soil and foliar Zn-EDTA application at two stages of crop growth. The results revealed that soil application of $ZnSO_4$ @ 25 kg ha^{-1} recorded the highest grain yields (62.9 q ha^{-1}) which was at par with soil application of $ZnSO_4$ @ 20 kg ha^{-1} (61.5 q ha^{-1}) whereas, decline in grain yield of maize was observed at higher level of zinc soil application. Among the methods of zinc application, the combination treatment of seed fortification by 0.5 % of Zn-EDTA and two sprays of 0.2 % Zn-EDTA at 5^{th} leaf stage and tasseling stages recorded relatively highest grain yield (59.0 q ha^{-1}) when compared to seed fortification and foliar application alone. Soil application of Zn explicitly influenced the Zn uptake by maize crop. The significantly highest Zn uptake was recorded by treatment application of $ZnSO_4$ @ 25 kg ha^{-1} (545 g ha^{-1}) which was at par with treatment, application of $ZnSO_4$ @ 20 kg ha^{-1}(532 g ha^{-1}). The accumulation of DTPA extractable Zn in the soil varied considerably within the treatments. Significant higher accumulation of DTPA extractable Zn was recorded by soil application of $ZnSO_4$ @ 30 kg ha^{-1}(0.43 mg kg^{-1}) which was statistically at par withsoil application of $ZnSO_4$ @ 25 kg ha^{-1} (0.42 mg kg

$^{-1}$). The zinc fractions did not show much variation however, treatment receiving zinc through soil application showed increased concentration of Zn fractions *versus* other methods of zinc fertilization. In general, application of 30 kg $ZnSO_4$ ha^{-1} recorded higher concentration but no distinct trend was observed. The highest concentration of WS-Zn (0.17 mg kg^{-1}), S-Zn (0.08 mg kg^{-1}) CA-Zn (0.25 mg kg^{-1}) was recorded by application of 30 kg $ZnSO_4$ ha^{-1}. RES-Zn emerged as a dominant Zn fraction followed by OM-Zn. The Zn fractions were positively and significantly correlated with DTPA-Zn and Zn uptake and also exhibited positively and significantly correlated with each other.

IV-15. INTEGRATED NUTRIENT MANAGEMENT IN MAIZE (*ZEA MAYS* L.)

Pilane M.S., Karad S.R., Kumbhar S.D., Patil S.A. and Khot G.G.
All India Coordinated Research Project on Maize, Mahatma Phule Krishi Vidyapeeth, Kohlapur

Maize (*Zea mays* L.) is one of the most important cereal crop of the world and contributes to food security in most of the developing countries. In India, maize is emerging as a third most important crop after rice and wheat. Maize is cultivated in a variable range of conditions with wide range of production environments. With green revolution the productivity of the crops has been increased tremendously. The abundant use of chemical fertilizers with improved varieties are main reasons of this increase. However, one sided use of chemical fertilizers devoid of organic sources, have made our soils sick and problematic. It is essential to make the agriculture eco-friendly production system capable of sustainable growth in agriculture to meet the basic needs of rapidly increasing population. Balanced use of nutrients is very essential for this. Therefore, an experiment comprised of eleven treatments has been conducted at AICRP on Maize, Kolhapur in randomized block design with three replications for two years (*viz*., *Kharif* 2018 and *Kharif* 2019). The treatments comprised of chemical fertilizers, organic manures and organic plus inorganic fertilizers. Among the various treatments T7 (100% RDF + 5t/ha FYM) recorded highest grain and stover yield (68.52 and 103.94 q/ha, respectively) followed by T10 (100% RDF + 5 kg/ha Zn) (64.08 and 96.37 q/ha) and T2 (100% RDF) (61.89 and 94.45 q/ha). These treatments were also found superior for important agronomic traits viz., plant height, number of cobs/ha and 100 seed weight. The treatment T7 comprising of 100% RDF (120:60:40 kg N:P:K /ha) plus 5 tonnes FYM per ha is recommended for maize cultivation in Maharashtra.

IV-16. PRODUCTIVITY AND PROFITABILITY OF SWEET CORN (*ZEA MAYS* L. *SACCHARATA* STURT)-BASED INTERCROPPING SYSTEMS

Menia M.[1] and Saad A.A.[2]
[1]Division of Agronomy, Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences and Technology- Jammu, Main Campus, Chatha
[2]Division of Agronomy, Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir, Wadura, Sopore
monikamenia2019@gmail.com

A field experiment was conducted during *kharif* season of 2017 at the Agronomy Research Farm, Faculty of Agriculture of Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Wadura to evaluate the productivity and resource- use efficiency of intercropping of sweet corn (*Zea mays* L. *saccharata* Sturt) with Rajmash (*Vigna vulgaris* L.) and soybean (*Glycine max* L. Merril). The intercrops were grown in additive series with sweet corn as regular rows of 1:1 and paired rows of 2:1 and 2:2. The experiment was laid out in randomized block design having three replications. Among intercropping, sweet corn grown in association with soybean in 1:1 recorded significantly higher values of growth parameters such as plant height, LAI and percent PAR intercepted. Among different intercropping combinations, the highest corn equivalent yield (CEY) of 24.8 t/ha was also with sweet corn + soybean in 1:1 row ratio. The nutrient-use efficiency of NPK applied and irrigation water-use efficiency were the highest with the same treatment. The highest benefit cost ratio of 9.00 was also worked out with sweet corn + soybean (1:1) intercropping system. From the present study, it was concluded that intercropping of sweet corn with soybean in regular rows of 1:1 ratio could achieve higher productivity and profitability among different intercropping systems.

IV-17. PERFORMANCE OF SWEET CORN BASED CROPPING SYSTEMS UNDER DIFFERENT CROP COMBINATIONS AND NUTRIENT MANAGEMENT PRACTICES IN RAINFED UPLAND

Swain B.[1], Naik P.[2], Swain D.[2], Paikaray R.K.[1] and Garnayak L.M.[1]

[1]Department of Agronomy, Odisha University of Agriculture and Technology, Bhubaneswar

[2]AICRP on Maize, Odisha University of Agriculture and Technology, Bhubaneswar

A field experiment was conducted to study the response of sweet corn based cropping systems under different inter-crops and nutrient management practices in rainfed upland during 2017-18 at AICRP on Maize, OUAT, Bhubaneswar, Odisha. The soil was sandy loam with 4.7 pH and low in available N, high in available P and medium in available K. The experiment was laid out in a split-plot design in three replications with four cropping systems namely, C_1 (rice-Horsegram), C_2 (sweet corn- horsegram), C_3 (sweet corn + blackgram in 2:2-horsegram) and C_4 (sweet corn + cowpea in 2:2-horsegram) in main-plots and three nutrient management practices i.e., N_1 (Inorganic:- RDF), N_2 (INM:- soil test based 75% RDN + 25% N from FYM + lime 0.2 LR + biofertilizers consortium) and N_3 (Organic:- FYM, Vermicompost and Neem Oil cake to supply 1/3rd RDN each + biofertilizers consortium) in the sub-plots. Different inter-crops did not affect yield and yield attributes of sweet corn, though the sole crop registered numerically higher values of green cob yield (7.41 t ha^{-1}). INM package (N_2) resulted in maximum plant height, LAI, dry matter accumulation, CGR, RGR, NAR, cobs ha^{-1}, cob length, cob diameter, test weightand sweet corn cob yield of 8.48 t ha^{-1}, which was 18% and 38% higher than the inorganic (N_1) and organic practice (N_3), respectively. Inter-cropping did not affect the quality parameters of sweet corn. INM (N_2) resulted in the highest TSS (13.5^0 Brix), sugar (23.6%) and protein (9.4%) content being *at par* with 100% RDF. Horsegram grown on residual soil fertility after harvest of sweet corn intercropped with cowpea (C_4) produced seed yield of 932 kg ha^{-1}, being *at par* with other maize based cropping systems. Residual effect of INM (N_2) practice resulted in the maximum seed yield of horsegram (958 kg ha^{-1}), which was on a *par* with organic practice (N_3). Sweet corn + cowpea (2:2)-horsegram

system (C_4) under INM practice (N_2) produced the highest system yield of 12.20 t SEY ha^{-1} with B:C of 2.18. Nutrient uptake was maximum in sweet corn + cowpea-horsegram system (123.9 kg N, 92.5 kg P and 161.8 kg K ha^{-1}) and INM practice (130.8 kg N, 55.0 kg P and 158.0 kg K ha^{-1}). Inclusion of blackgram or cowpea as intercrops with maize increased the organic carbon, soil microbial biomass carbon pool and nutrient (N-P-K) status of the soil in organic practice (N_3) followed by INM practice (N_2). Hence, sweet corn based cropping systems involving legumes as intercrop and fertilized with integrated source of nutrients (N_2) were more productive, profitable and sustainable.

IV-18. EFFECT OF PLANTING GEOMETRY AND NUTRIENT MANAGEMENT ON THE PRODUCTIVITY OF MAIZE HYBRIDS UNDER RAINFED CONDITIONS OF ODISHA

Naik P.[1], Swain D.[1] and Nanda A.[2]
[1]AICRP on Maize, [2]FASAL, AICRP on Agrometeorology
Odisha University of Agriculture & Technology, Bhubaneswar

A Field experiment was carried out at AICRP on Maize, Odisha University of Agriculture and Technology, Bhubaneswar, Odisha during *kharif* for three consecutive years of 2014, 2015 and 2016 to find out the effect of planting geometry and nutrient management practices on productivity of hybrid maize in rainfed upland. The experimental arrangement was split-split plot design in three replications with two hybrids (V_1: Hishell & V_2: P3441) in main plots, two planting geometry (S_1: 60x20 cm^2 & S_2: 50x20 cm^2) in sub-plots and three nutrient management practices [N_1: Recommended dose of fertiliser (RDF), N_2: Site specific nutrient management (SSNM) & N_3: Soil test based crop response (STCR)] in sub-sub plots. The pooled results over three year revealed the response of hybrid maize to high density planting (50x20 cm^2) with 7.7% higher yield over normal density (60x20 cm^2). The high density planting (50x20 cm^2) resulted in significantly higher net return of 17.4% more over normal plant density (60x20 cm^2) with B:C ratio of 1.41 and 1.34, respectively. Among various nutrient management practices (RDF, SSNM & STCR), STCR was found to be significantly superior with 19.2%, 4.8% higher yield over SSNM and RDF, respectively. STCR practice significantly increased net return which was 7.0% higher over SSNM and 38.8% higher over RDF with B:C ratio of 1.46, 1.38 and 1.11 for three nutrient management practices, respectively. Hence, high planting geometry and STCR based nutrient management practices along with suitable maize hybrids are recommended for achieving targeted yield and enhancing the profitability of maize in *kharif* rainfed condition of Odisha.

IV-19. DESIGNING PLANT ARCHITECTURE FOR HIGH DENSITY PLANTING IN MAIZE: A STEP TOWARDS PRODUCTIVITY ENHANCEMENT

Sarkar A., Sandhu S.K. and Kumar M.
Maize Section, Department of Plant Breeding and Genetics
Punjab Agricultural University, Ludhiana
aditi-pbg @pau.edu

Achieving sustainable food security with limited arable land is a major challenge in today's scenario of changing climate and increasing global population. Maize plays an increasingly vital role in global grain production. Maize, a C4 plant, has high yield potential and is predicted to become the number one cereal in the world by 2020. With the menace of paddy straw burning issues and hence environmental consequences coupled with depletion of underground water, maize crop has more strongly emerged as a candidate for crop diversification during kharif season in Punjab but the wide gap in potential and actual productivity of maize hinders the economic viability and consequently wider adoption by the farmers in Punjab state. High-density planting which envisages higher productivity by increased plant population per unit area has undergone a constant evolution over the years, with the purpose of enhancing the crop yield and has been documented as is one of the research interventions to break the maize productivity plateau. Earlier studies in this domain indicated that crowding stress reduced the ability of plants to use soil N prominently during the post silking period. The increased incidence of lodging and biotic stresses has also been indicated. Recently, Punjab Agricultural University (PAU), Ludhiana has taken up designing plant architecture amenable to high density planting. It is expected that the high density apposite inbred lines would generate high density responsive hybrids. Understanding of the traits which makes the plant best suited to higher plant population is of critical importance for the improvement of maize productivity through high density planting. The identification of efficient inbred lines, with key variants which may facilitate to cope up crowding stress viz., altered plant height, leaf angle and area, ear placement, ear and kernel traits and maturity patterns, has been carried out. A germplasm stock available at PAU comprising materials from inbred lines from CIMMYT, Mexico; NBPGR, New Delhi, local collections; WNC, Hyderabad and inbreds from different pools being maintained at PAU were sown in plot of 4 rows of 4m each at 60 x 20cm plant to plant and row to row spacing, respectively in kharif, 2019. About 50 lines were identified which harbored traits contributing towards HDP. Amongst selected lines, PML 1049, PML 387, JCY-45, PML-368 and JCY 31-1 possessed the maximum number of traits contributing towards suitability to HDP. These lines have been identified with narrow, erect to semi erect leaves with leaf angle ranging from 450-600, medium high ear placement, less number of branches in tassel and stay green plant habit.

These inbred lines can be utilized in breeding program for development of hybrids tailored for high density planting thus, contributing towards productivity enhancement.

IV-20. EFFECT OF PLANTING DENSITY AND NUTRIENT MANAGEMENT PRACTICES ON THE PERFORMANCE OF HYBRIDS IN KHARIF AND RABI SEASON

Sivamurugan A.P. and Ravikesavan R.
Department of Millets, Tamil Nadu Agricultural University, Coimbatore

Field experiments were conducted at Department of Millets, Tamil Nadu Agricultural University, Coimbatore during *kharif* and *Rabi*, 2017 to study the effect of planting density and nutrient management practices on growth and yield attributes of maize hybrids. During *Kharif*, 2017, the soil was sandy clay loam and medium in available N (314 kg/ha), P (20.0 kg/ha) and high in available K (473 kg/ha) with a pH of 8.26. During *Rabi*, 2017, the soil was low in available N (202 kg/ha), medium in available

P (21.0 kg/ha) and high in available K (635 kg/ha) with a pH of 8.32. In *Kharif*, 2017, in the main plot, two hybrids *viz.,* CO 6 and NK 6240 and in the sub plot, two spacings *viz*., 60 × 20 cm and 50 × 20 cm and in the sub sub plot, three nutrient management practices *viz*., RDF (250:75:75 NPK kg/ha), STCR (142:82:38 NPK kg/ha) and SSNM (110:61:90 NPK kg/ha) and during *Rabi*, 2017 with same main and sub plot with the sub sub plot, having three nutrient management practices *viz*., RDF (250: 75:75 NPK kg/ha), STCR (191:80:38 NPK kg/ha) and SSNM (110:61:90 NPK kg/ha) were tried in three replications. Experimental results revealed that Maize hybrid CO 6 recorded the maximum grain yield of 6727 kg ha^{-1} which was comparable with NK 6240. Among the planting densities, 50 x 20 cm recorded higher yield (6755 kg ha^{-1}) and it was comparable with 60 x 20 cm .Among the nutrient management practices, RDF recorded higher yield (7511 kg ha^{-1}) which was significantly superior to STCR during *Kharif*, 2017.In *Rabi*, 2017 Maize hybrid CO 6 registered the maximum grain yield of 6955 kg ha^{-1} which was significantly superior to NK 6240. Among the planting densities, 50 x 20 cm recorded higher yield (6978 kg ha^{-1}) and it was significantly superior to 60 x 20 cm. Among the nutrient management practices, RDF recorded higher yield (7567 kg ha^{-1}) which was superior to STCR and SSNM .Based on the results of two seasons of experimentation, it is concluded that Maize hybrid CO 6 under 50 × 20 cm spacing with the RDF (250:75:75 NPK kg/ha) recorded higher grain yield (8086 kg ha^{-1}), net return (Rs.77, 344 ha^{-1}) and B: C ratio (2.35).

IV-21. STUDIES ON THE INFLUENCE OF INTEGRATED NUTRIENT MANAGEMENT PRACTICES ON GRAIN YIELD OF MAIZE

Sivamurugan A.P. and Ravikesavan R.
Department of Millets, Tamil Nadu Agricultural University, Coimbatore

Field experiment was carried out at Department of Millets, Tamil Nadu Agricultural University, Coimbatore during *Kharif*, 2018 to study the influence of organic manures and inorganic fertilizers on the yield attributes and yield of maize hybrid CO 6. The soil was sandy clay loam and low in available N, medium in available P and high in available K. The treatments *viz*., Unmanured, 100% RDF, 75% RDF, 50% RDF, FYM 10t/ha + Azatobactor, Maize + legume intercropping with FYM 10 t/ha + Azatobactor, 100% RDF + 5 t/ha FYM, 75% RDF + 5 t/ha FYM, 50% RDF + 5 t/ha FYM, 100% RDF + 5 kg Zn/ha and FYM 5 t/ha were tried in three replications. Experimental results revealed that the treatments evinced significant influence on yield attributes and yield of maize. Among the different treatments, 100% RDF + FYM 5 t/ha recorded higher plant height (224.8 cm) at harvest, cob length (19.3 cm), cob girth (15.9 cm), no. of grain rows/cob (14.9) and no. of grains/row (34.1).There was no significant influence of treatments in respect of No. of grain rows/cob, No. of grains/row and 100 seed weight. In respect of yield, 100% RDF + FYM 5 t/ha recorded higher grain yield of 7324 kg ha^{-1} which was comparable with 100% RDF + 5 kg Zn/ha, 100% RDF, 75% RDF + 5 t/ha FYM and 75% RDF .The lowest yield of 3533 kg ha^{-1} was recorded in Unmanured treatment. Based on the results of experimentation and economics, it is concluded that application of 100% RDF (250:75:75 NPK kg/ha) recorded higher grain yield (7244 kg ha^{-1}), net return (Rs.72132/ha) and B: C ratio (2.48) in Maize hybrid CO 6.

IV-22. EFFECTS OF LONG-TERM TILLAGE AND RESIDUE MANAGEMENT PRACTICES ON PEST INFESTATION IN *RABI* MAIZE IN MAIZE-MAIZE-*SESBANIA* SYSTEM

Suby S.B.[1], Parihar C.M.[2], Jat S.L.[1], Kumar N.[1], Gambhir G.[1]and Rakshit S.[1]
[1]Delhi Unit Office, ICAR-Indian Institute of Maize Research, New Delhi
[2]ICAR-Indian Agricultural Research Institute, New Delhi
subysb@gmail.com

Conservation agriculture based crop management of no tillage and residue retention found to be resource efficient, productive and remunerative in maize based cropping system in India (Parihar et al., 2016). Understanding the dynamics of key pests in varying tillage and residue management practices will help to custom design system based sustainable crop protection practices. In India, major pests of maize are spotted stem borer (*Chilo partellus* Swinhoe) in *kharif*, pink stem borer (*Sesamia inferens* Walker) in *rabi* and shoot fly (*Atherigona* spp.) in spring seasons. Fall armyworm (FAW) (*Spodoptera frugiperda* J. E. Smith), which invaded India in 2018 was found to damage both *kharif* and *rabi* maize. Effect of tillage practices [permanent beds with residue (PB), zero tillage (ZT) and conventional tillage (CT)] on infestation *S. inferens* in maize-maize-*Sesbania* system was studied in a long term experiment going on at fixed site since 2008. Infestation of *S. inferens* was identified by the sudden wilting and/or dying of the central whorl called 'dead heart' in V_3-V_6 stage maize plants, recorded during *rabi* seasons of 2017-18, 2018-19 and 2019-20 (up to December 2019). The highest percentage infestation of *S. inferens* was observed in PB (10.4 to 26.1 %), followed by ZT (5.7 to 20.2 %) and least in CT (4.8 to 6.2 %), with significant differences over the years. In 2020, heavy infestation of FAW was also observed as high as 99.5% in CTand the least in ZT (84.19%). Severity of damage in terms of Davis score 1-9 (Davis and Williams, 1992) was assessed, where least severity was observed in ZT and highest in CT. However, CT recorded low survival of FAW and high recovery of plants in subsequent observations. Since FAW feeds on plant whorl, while *S. inferens* infests the base, system needs to be observed closely in the coming years.

IV-23. SEASONAL CHANGES IN SOIL HEALTH PARAMETERS AFFECTED BY NITROGEN AND RESIDUE MANAGEMENT PRACTICES UNDER LONG-TERM CONSERVATION AGRICULTURE IN MAIZE SYSTEM

Jat S.L., Gambhir G., Kumar N., Suby S.B, Parihar C.M. and Rakshit S.
Delhi Unit Office, ICAR-Indian Institute of Maize Research, New Delhi
ICAR-Indian Agricultural Research Institute, New Delhi
sliari@gmail.com

Conservation agriculture based management found to be effective for enhancing productivity, profitability and soil properties in maize based cropping system. We have assessed changes in the key soil enzymatic activities under long-term CA in spring and kharif season. In our experiment, the zero-tillage practices with residue (WR) and without residues (WoR) with two maize cropping system (MMuMb: Maize-Mustard-Mungbean and MWMb: Maize-Wheat-Mungbean) considered as main-plots and further in four different nitrogen management (F0: RDN, F1: 33+GS (green seeker), F2: 50+GS, F3: 70+GS) in sub-plots. The soil was sampled after harvest of spring 2019 and kharif 2019 for analysis of the soil organic carbon and NPK in the experiments started at fixed site since *kharif* 2012. The enzymatic properties were analyzed at the flowering stage of the crop during spring mungbean and kharif maize. Compared to CT plots, the soil physical properties like penetration resistance (PR) showed significant ($P < 0.05$) declined at various depths. The soil organic carbon (SOC) increased in MWMb in F1 at with residue in 0-15 and 15–30 cm depths while SOC increased in MMuMb without residue in F3. In all enzyme activity assays, at flowering of *kharif* season showed better enzyme activity as compared to summer season whereas in macronutrients (NPK) showed higher values in soils after harvest of summer season. For microbial biomass carbon (MBC), MMuMb showing highest activity in both the depths but at different nitrogen management practices. For florescein diacetate (FDA), at 0-15 cm depth, MMuMb showed highest activity with residue at F3 whereas at 15-30 cm depth, MWMb has highest activity without residue. At both the depths, highest urease activity was observed in same cropping system i.e. MWMb but with different nitrogen doses (F4 and F1). Alkaline phosphatase activity was more in MWMb with residue at RDN in 0-15 cm depth whereas in 15-30 cm depth, MMuMb showed highest activity with residue at RDN. In glucosidase enzyme assay, MMuMb has highest activity in RDN with residue and at 15-30 cm depth, highest activity was observed in another cropping system MWMb but with same dose of nitrogen. The nitrogen was highest in MMuMb with F2 at 0-15 cm and in 15-30 cm. The potassium content in both the depths was highest in MWMb system at F3 whereas highest phosphorous was observed in MMuMb at 0-15 cm depth while in MWMb at 15-30 cm depth. Hence, it can be concluded that residue retention in the conservation agriculture improved the enzymatic activities and NPK content along with decreases the penetration resistance.

IV-24. COMPARATIVE EVALUATION OF SEEDLING GROWTH TRAITS AND DRY MATTER PARTITIONING TO ROOTS IN MAIZE INBREDS AND HYBRIDS

Reddaiah K.[1], Gadag R.N.[1], Mukri G.[1], Pandey R.[1], Kumari J.[2] and Bhat J.[1]
[1]ICAR-Indian Agricultural research Institute, New Delhi
[2]ICAR-National Bureau of Plant Genetic Resources, New Delhi
ganapati4121@gmail.com

Heterosis is typically detected in adult hybrid plants as increased yield or vigor compared to their parents. Heterosis is observed at different growth stage of the plant. Little is known about the manifestation of heterosis at early growth stages. Seedling stage is the earlist possible stage where one can quantify superiority of the given genotype by evaluating them for various growth parameters. As heterosis is the superiority of the hybrids over its parents, for underlying traits, we tried to compare the hybrids and their parents at seedling stages. Total four hybrids and five inbred lines were evaluated at seedling stage for their seedling vigor index, shoot length, seedling dry weight, root length, root surface area, root projected area, root diameter, root volume, root dry weight. Seedling traits were recorded 7 days after sowing. Root parameters were recorded through root image scanner (WinRHIZO Pro) at 14 and 21 days after transplanting under hydrophonics. Hybrids, AH 4158, AH 4271, PJHM-1 and inbreds, PML 105 and UMI 1210 showed mean highest seedling vigor index (SVI) as well as total root length. Mid parental heterosis for SVI of AH 4158 was highest

(81.50%) followed by AH 4271 (66.05%) where as for all the root parameters under study, AH 4271 showed highest mid parental heterosis compared to AH 4158. It was evident from the study that, root parameters are significantly correlated with the dry matter accumulation at seedling stage. Hence, the phenomenon of heterosis at different growth stage needs to be dissected to understand the role of early growth parameters in deciding the heterosis in maize.

IV-25. PRODUCTION, PRODUCTIVITY AND PROFITABILITY OF MAIZE (*ZEA MAYS*) AS INFLUENCED BY DIFFERENT AGRONOMIC PRACTICES

Lakra A.K. and Sinha A.K.
Section of Agronomy
Indira Gandhi Krishi Vishwavidyalaya, Rajmohini Devi Collage of Agriculture and Research Station, Ambikapur

Field experiments were conducted at Research farm of RMD College of Agriculture & Research Station, Ambikapur to study the effect of different agronomical practices on production, productivity and profitability of maize during 2017-20. There were eight treatments *viz.* farmer practices, ecological intensification (EI), EI- tillage practices, EI-nutrient management, EI- planting density, EI- water management, EI-weed management and EI- disease and insect management which were laid out in randomized block design (RBD) and replicated thrice. Ecological intensification treatment recorded higher growth and yield attributing features of maize were significantly influenced by different management practices. Maximum cob length, cob girth, number of kernel/cob, number of kernel/row and test weight of maize were obtained from ecological intensification treatment over rest of the treatment. The kernel yield of maize recorded at ecological intensification (67.45 q ha^{-1}) was significantly higher than all other management treatments. However, it was on a par with that obtained at EI-water management (63.48 q ha^{-1}) and EI- disease and insect management (6191.55 q ha^{-1}). The highest net returns of maize was recorded under ecological intensification (56958.68 $Rs.ha^{-1}$) followed by EI-water management (56517.42 $Rs.ha^{-1}$), while returns per rupee of investment were obtained with EI-water management (1.36) which was at par with ecological intensification treatment (1.34). Ecological intensification recorded significantly minimum total weed density (61.49 m^{-2}) and weed dry weight (14.73 g) as compared to all other treatments.

IV-26. INTERCROPPING OF MAIZE (*ZEA MAYS*) WITH BEAN (*PHASEOLUS VULGARIS*) INFLUENCED BY VARYING TILLAGE AND FERTILIZER MANAGEMENT PRACTICES UNDER RAINFED CONDITIONS OF KASHMIR VALLEY

Bhat S.F., Saad A.A., Kanth R.H., Masood A., Nazir A., Bhat T.A. and Rather M.
Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Shalimar
bhatsuhailm@gmail.com

A field experiment was conducted during *kharif* season of 2016 at the Research Farm of Faculty of Agriculture and Regional Research Station, Wadura of SKUAST-K to evaluate the performance of intercropping of maize (Shalimar Composite-4) with bean (WB-1634) in the row ratio of 1:1 under conventional and zero tillage having varying fertility levels (control, 75%RFD,100%RFD). The experiment was conducted in split plot design keeping tillage (conventional & zero tillage) and cropping system (sole & intercropping) in main plots and fertility levels in sub-plot. Bean was intercropped with the various fertility levels of maize. Under zero tillage land was prepared by applying glyphosate (41% EC) at the rate of 1.0 kg a.i. ha^{-1}.Sowing of maize and pole bean was done by opening narrow furrow at a row distance of 60 cm. The growth parameters of both the crops were significantly affected by the treatments. Growth parameters of maize and pole bean were significantly higher with conventional tillage- sole systems (CSM & CSB) followed by conventional tillage-intercropping of maize+bean system (CMB). Grain yields of maize and pole bean were also higher with conventional tillage- sole systems. These parameters were also higher with 100% RFD irrespective of tillage & cropping system. Among interaction of treatments, grain yields of maize and pole bean were higher in conventional tillage-sole cropping of the respective cropsalong with 100% RFDand conventional tillage-intercropping of these crops (CMB × 100% RFD). However zero tillage- sole maize along with 100% RFD was at par to conventional tillage- sole maize along with 100% RFD. Significantly higher system productivity was observed with conventional tillage- intercropping at 100% (CMB × 100% RFD) followed by intercropping under zero tillage at 100% RFD (ZMB × 100% RFD) and intercropping under conventional tillage at 75% RFD (CMB × 75% RFD). The yield advantage (LER) under CMB × 100% RFD was only about 6.6% higher than ZMB × 100% RFD. Maize crop was more aggressive than pole bean in conventional tillage zero tillage system, irrespective of fertility levels. With respect to fertility level, maize was more aggressive in control plots, however at 75% RFD of maize both the component crops were equally competitive. But at 100% RFD, pole bean became more aggressive than maize crop. Nutrient-use efficiency was higher with CSB &CMB followed by ZSB & ZMB. However energy-use efficiency was higher with ZMB.The results concluded that intercropping of maize and bean under zero tillage supplied with 100%RFD of maize was the next alternative after conventional intercropping supplied with 100%RFD of maize.

IV-27. EFFECT OF DIFFERENT TILLAGE PRACTICES AND NUTRIENT MANAGEMENT ON PRODUCTIVITY OF MAIZE (*ZEA MAYS* L.) IN MAIZE-MUSTARD CROPPING SYSTEM

Mahajan G. and Paradkar V.K.
AICRP on Maize, Zonal Agricultural Research Station, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Chhindwara
aicrpagrorewa@gmail.com

The moisture and nutrient up taking capacity of plants is highly determined by the spatial distribution of the root system through the soil profile and it ultimately affects the growth and productivity of crop. In a general view the distribution of underground parts of plant in soil is directly effect by the soil compaction or the tilth of soil. As compared to conventional tillage, minimum tillage protects the soil from wind and water erosion, favours microbial growth, improved soil structure, increase infiltration rate, soil respiration, dehydrogenase activity in upper layer, soil organic carbon and soil microbial biomass. Fertilizer application recommendations are often based on crop response data averaged over large areas, though farmers' fields show large variability in terms of nutrient-supplying capacity and crop response to nutrients.

Thus, blanket fertilizer application recommendations may lead farmers to over-fertilize in some areas and under-fertilize in others, or apply an improper balance of nutrients for their soil or crop. An alternative to blanket guidance, Site-Specific Nutrient Management (SSNM) aims to optimize the supply of soil nutrients over time and space to match the requirements of crops. Keeping these facts in consideration, the present investigation was carried out to find out Effect of different tillage practices and nutrient management on productivity of maize (*Zea mays* L.) in maize-mustard cropping system. The study was conducted during *Kharif* season of 2017, 2018 & 2019 consecutively at a fixed site at JNKVV, Zonal Agriculture Research Station, Chandangaon, Chhindwara. It is situated at a height of 682m above mean sea level with a latitude range of 21° 28' N and longitude range of 78° 10' E. It receives an average rainfall of 1084 mm during the crop period the rains were normal. The experiment was laid out in split block design keeping with six treatments viz: Tillage practices as main plot factor (Zero Tillage, Conventional tillage & Permanent bed) whereas, the sub plot treatment includes nutrient management practices (½ RDF, RDF & SSNM based on nutrient expert i.e.140:34:71; $N:P_2O_5:K_2O$ kg/ha) where the RDF was 120:60:40; $N:P_2O_5:K_2O$ kg/ha. The experiment was laid out with three replications. The results from the present experiment clearly indicate that under the climatic conditions of Chhindwara, the method of conventional tillage planting gave higher yield. Amongst nutrient management practices, SSNM resulted in significantly higher yield over rest of the nutrient management options.

IV-28. EFFECT OF TILLAGE PRACTICES AND HYDROGEL DOSES ON THE PRODUCTIVITY OF MAIZE (ZEA MAYS L.) UNDER RAINFED CONDITIONS

Paradkar V.K. and Mahajan G.
AICRP on Maize, Zonal Agricultural Research Station, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Chhindwara
aicrpagrorewa@gmail.com

Maize is the third most important cereal crop in India after rice and wheat. maize can be grown throughout the year in summer, autumn, winter and spring seasons. Under rainfed condition during *kharif* season, it suffers from natural calamities such as frequent and heavy rainfall or drought with heavy infestation of diseases and insect-pests. As such, the average yield of *kharif* maize is low. Water is an important life saving natural resource for the crop. It profoundly influences photosynthesis, respiration, absorption, translocation and utilization of mineral nutrient and cell division. The use of soil conditioners like hydrogel has a great potential to exploit the existing water in soil for agricultural crops by increasing their production. When hydrogel is incorporated into the soil it is presumed that they retain large quantities of water and nutrients, which are released as required by the plant. Thus, plant growth could be improved with limited water supply. The incorporation of super absorbent polymer enhanced seed germination and emergence, crop growth and yield. The present investigation was carried out for Enhancing water-use efficiency in rainfed maize. The study was conducted during *Kharif* season of 2017& 2018 at JNKVV, Zonal Agriculture Research Station, Chandangaon, Chhindwara. It is situated at a height of 682m above mean sea level with a latitude range of 21° 28' N and longitude range of 78° 10' E. It receives an average rainfall of 1084 mm during the crop period the rains were normal. The experiment was laid out in split block design keeping with twelve treatments. The main plot treatments included tillage viz: T1= Tillage Conventional; T2= Tillage Conventional + Mulching; T3= Zero tillage and T4= Zero tillage + Residues whereas sub ploy treatment includes application of hydrogel to crops viz: G1= Hydrogel control; G2= Hydrogel 2.5 g gel and G3= Hydrogel 5.0 g gel. The results of the study showed that the rainfed maize responded to tillage practices. It was found that zero tillage + mulch resulted yield enhancement by 24 % higher yield over without mulch. Amongst various hydrogel treatments the application of hydrogel @5.0 kg/ha resulted yield increment by 10.9% at, Chhindwara over no hydrogel application.

IV-29. PRODUCTION POTENTIAL AND ECONOMIC FEASIBILITY OF MAIZE AND PULSE INTERCROPPING IN DIFFERENT ROW RATIOS UNDER RAINFED CONDITIONS OF NORTH- EAST INDIA

Singh S.D., Nongmaithem N., Konsam J. and Senjam P.
Directorate of Research, Central Agricultural University, Imphal
sanj_day@yahoo.com

A field experiment was conducted during *kharif* season of 2016-17 at upland research farm of ICAR, Mizoram centre, Kolasib. The experiment was undertaken to evaluate the effect of maize and pulse intercropping under different row ratios on its yields, yield attributing characters, intercropping efficiencies and monetary return. The results of the experiment showed the yield and yield attributing parameters of the sole crops were higher than the yields in intercropping system. There was a trend of decreasing maize yield with increasing row ratio in intercropping treatments, however, the intercrops (soyabean and green gram) yield were increased with increase of row ratios. Maize intercropping with green gram at 1:2 ratios produced the maximum land equivalent ratio (1.471) and land equivalent coefficient (0.536) whereas maize+soyabean in 1:2 ratio produced the highest area time equivalent ratio (1.270). Among the competition indices, relative crowding coefficient value (11.672) was maximum under maize+green gram in 1:1 ratio. There was positive aggressivity of maize and negative aggressivity in soyabean and green gram. In terms of monetary return parameters such as maize equivalent yield, system productivity, production efficiency, net return and B:C ratio were attributed to maize+soyabean at 1:2 ratios.

IV-30. EFFECT OF DETOPPING ON YIELD OF MAIZE CROP

Rajanikanth E., Manjulatha G., Sravani D., Usharani G. and Vijayabhaskar A.
Agricultural Research Station, Karimnagar
Professor Jaya Shankar Telangana State Agricultural University

Now days fodder is the main constraint in particularly during *rabi* season. In maize growing areas, the de-topped Maize is one of the alternative sources of fodder, which may be used as green fodder. Hence to find out the effect of detopping on Maize yield this experiment was planned. A field experiment was conducted at Agricultural Research Station, Karimnagar for two years during *Rabi* 2013-14 & 2014-15, to find out the effect of de-topping on maize yield in red sandy loam soils. The initial soil status indicated of high available N, P, K (613.9, 62.8, 436 kg/ha respectively). The experiment was carried out in Randomized block design in two sub experiments. First sub-experiment conducted with 7 treatments (Stages of De-topping *i.e* T1 - 14 Days after tasseling (DAT), T2 - 19 DAT, T3 - 24 DAT, T4 - 29 DAT, T5 - 34 DA7, T6 - 40 DAT & Control -Without De-topping) and with 6 treatments in second sub-experiment (Length of De-topping *i.e* T1 - The fifth node above the cob, T2 - The fourth node above the cob, T3 - The third node above the cob, T4 - The second node above the cob, T5- One node above the cob & T6- Control (Without De-topping). Significantly higher grain yield and yield attributes were recorded with control (no detopping) and it was on par with detopping (by leaving five leaves above the cob) at 40 days after tasseling in addition green fodder yield of 1.96 t/ha is obtained. Detopping by leaving two, three and four leaves above the cob placement resulted in 22, 18 & 17% yield loss respectively than compared to the control.

IV-31. AGRONOMIC INTERVENTIONS TO ENHANCE THE PRODUCTIVITY OF KHARIF MAIZE (*ZEA MAYS* L.)

Kumar M., Chawla J.S. , Sandhu S.K., Garg T. and Singh G.
Maize Section, Department of Plant Breeding and Genetics, PAU Ludhiana
maheshkumarvats@pau.edu

In Punjab, the optimum time for sowing of *kharif* maize is from last week of May to end of June. The planting of maize during *kharif* season experienced high rainfall in monsoon season which often causes temporary flooding in flat method of sowing, there by affecting its germination. Efforts were made to device alternate methods *viz*., bed or ridge planting which may lead to higher grain yield than the flat sowing method due to better germination, good plant establishment, increased nutrient use efficiency, better irrigation management, better weed management through inter bed cultivation and increase aeration in root zone. These methods may resist lodging and will produce higher grain yield than flat sowing. The field experiments were conducted to find out the appropriate planting method to enhance the germination during *kharif* 2017 and 2018 at Punjab Agricultural University, Ludhiana. The experiment comprised of 15 treatment combinations with three planting methods as main plot treatments (flat, ridge and bed sowing) and five nitrogen levels as sub plot treatments (0, 90, 120, 150 and 180 kg N ha^{-1}) in a split plot design. The N was applied in the form of urea in three equal splits, at sowing, knee high stage and pre-tasseling stage. The sowing was done by dibbling method. The row to row spacing of 60 cm and plant to plant spacing of 20 cm was kept for flat and ridge sowing methods and row to row spacing of 67.5 cm and plant to plant spacing of 18 cm was kept for bed sowing. Significantly higher grain yield was obtained in bed sowing as compared to flat sowing irrespective of nitrogen levels. The yield contributing attributes like number of cobs, cob length, girth, number of rows per cob were higher in bed sown crop. Maize crop sown on beds and ridges gave 14.9 and 9.7 per cent higher yields than flat sowing, respectively. The yield response with respect to nitrogen application was recorded upto 150 kg/ha. On the basis of two years data, the yield at 150 kg N/ha (64.2 q/ha) and 180 kg N /ha (65.8 q/ha) were at par but significantly higher than lower test doses. The yield response at higher nitrogen level (150 kg/ha), as compared to recommended level of 120 kg N/ha, may be due to low organic carbon (0.36%) of the experimental plot. Based on experimental results, it was concluded that maize crop should be sown on beds using recommended dose of nitrogen fertilizer during *kharif* season for better crop stand, to avoid water stress due to excessive rainfall and may leads to higher yield.

IV-32. PRECISION NITROGEN MANAGEMENT THROUGH OPTICAL SENSOR TOOL

Sreelatha D.[1], Anuradha G.[1], Reddy M.L.K[1], Madhavi A.[2] and Srijaya T.[2]
[1]Maize Research Centre, ARI, PJTSAU, Rajendranagar, Hyderabad
[2]AICRP on STCR, ARI, PJTSAU, Rajendranagar, Hyderabad

Farmers tend to apply higher rates of N fertilizer than recommended to ensure maximum yield. Excessive N rates for the yield attained often results in unused N moving to ground and surface water in the form of nitrate and result in sizeable fertilizer N losses, not only reduces grower profits but can also lead to environmental contamination. Use of proximal plant canopy sensors offers an opportunity for corn producers to adjust N requirement according to the crop requirement and demand. Hence, a three years (2017-19) field study was conducted in sandy clay loam soils having medium Nitrogen, high Phosphorus and Potassium status (288-92-513 N-P2O5-K2O/ha) during *kharif* season in Randomized block design with twelve treatments consists of Control (No N, only Recommended P&K); RDF(200-60-50); STCR(246-52-60); NE(141-60-90);and remaining treatments (T5 to T11) were formulated with 33%, 60% and 70% as basal ,30%+30% and 35%+35% as basal and 25 DAS with recommended N and remaining N doses based on NDVI readings obtained with green seeker at knee high and tasseling stages were tested with T12 -N-rich Strip(300-60-40 N-P_2O_5-K_2O/ha) treatment.The pooled results revealed that, N-rich strip (300-60-40 N-P_2O_5-K_2O/ha) has realized significantly higher grain yield (8.9 t/ha) compared to all other treatments. However, Soil test based recommendation (8.6 t/ha) and RDF (8.0 t/ha) gave grain yields on par with N-rich strip. Hence, the N-requirement can be given through STCR to save N-dose (54 kg N/ha). Further, it is revealed that the green seeker based N-applications at knee-high and tasseling stages with various treatments also realized yields (7.5 to 8.1 t/ha) which are on par with RDF. Among the green seeker based N-application treatments, the treatment 11(35% basal N (66 kg N/ha)+ 35% at 25 DAS (66 kg N/ha) +Green seeker based N at tasseling stage (35 kg N/ha) has realized highest maize grain yield (8.1t/ha). Hence, the results reveals that green seeker based application is the best option with saving of 33 kg of N/ha compared to RDF.

IV-33.EFFECT OF PLANTING METHODS AND MULCHING ON GROWTH AND YIELD OF SPRING MAIZE (Z*EA MAYS* L.) HYBRIDS

Singh M. and Kumar M.
Department of Agronomy
Punjab Agricultural University, Ludhiana
manmeet9980@gmail.com

A field experiment was conducted at Punjab Agricultural University, Ludhiana during spring 2017 and 2018 to study the influence of planting methods (bed, ridge and flat planting) two mulching levels (no mulch and paddy straw mulch @ 5 t ha^{-1}) and three hybrids (PMH 10, PMH 8 and DKC 9108) on the growth and yield of spring maize. The experiment was laid out in a split plot design with three replications. The experiment was conducted in loamy sand soil having normal pH, electrical conductivity and organic carbon, medium in available nitrogen, high in available phosphorus and potash. In bed and ridge planting methods was significantly high growth parameters like plant height, no. of leaves, leaf area index and dry matter accumulation per plant as compared to flat sowing method. In bed planting method maximum grain yield of 80.4 q ha^{-1} and 78.4 q ha^{-1} in 2017 and 2018 respectively recorded which was statistically at par with ridge planting method (79.9 q ha^{-1} in 2017 and 77.7 q ha^{-1} in 2018) but was significantly higher than that recorded under flat sowing. Significantly increased growth parameters with paddy straw mulching 5 t ha^{-1}as compared to no mulching. Application of mulch increased grain yield by 7.8 per cent in 2017 and 5.0 per cent in 2018 as compared to no mulch treatments. Among the different hybrids, DKC 9108 and PMH 10 produced better growth parameters as compared to PMH 8. DKC 9108 recorded highest grain yield but was statistically at par with PMH 10 while PMH 8 recorded significantly lower yield but was at par with PMH 10.

Theme-V

Mechanization, Processing and Value Addition - Key for Maize Growth

V-1. GLYCEMIC INDEX (GI) OF MAIZE BASED PRODUCTS UNDER DIFFERENT COOKING METHODS

Shobha D.[1], Joshi N.[2] and Pooja H.D.[1]
[1]AICRP on Maize, Zonal Agricultural Research Station, V.C. Farm, Mandya
[2]Department of Food Science and Nutrition, Gandhi Krishi Vigyana Kendra, Bengaluru
shobhafsn@gmail.com

Carbohydrate foods consumed with same amount of glucose produce different glycemic responses depending on the nature of food, type and extent of food processing or cooking. Considering this, a study was conducted to assess the glycemic index of maize based products under different cooking methods .Maize products were standardized using traditional cooking methods such as toasting; maize *roti* (100 % maize flour), boiling; maize *upma* (100 % maize semolina), steaming; maize *kadabu* (75 % maize flour + 25 % black gram flour) and fermentation; maize *idli* (75 % maize semolina + 25 % black gram). The GI of the products was estimated as per WHO, (2003) protocol. Ten healthy volunteers aged between 20-25 years participated in the study. Test foods (50 g carbohydrate) were provided on different days after an overnight fast. Blood samples were drawn by finger prick method using glucometer (Accu-check active) at 0, 30, 60, 90 and 120 minutes after the meal. The GI was calculated by dividing the incremental area under the curve (IAUC) for the test food by that for the standard food (IAUCS). The nutritional composition of the products was estimated by standard AOAC (2000) method. The study revealed that, among different cooking methods , steam cooked products (*Kadabu and Idli*) were found to be superior with moisture (37.41%, 38.81 %), protein (8.47%, 12.45 %), fat (2.25%, 1.95%), ash (1.77 %, 1.62 %) carbohydrate (42.01%, 72.43 %) and energy (221.56 ,356 K cal/ 100g), respectively .The glycemic index (GI) of the maize products under different cooking methods revealed that GI of maize kadabu (56.91), maize idli (61.78) were found to fall under moderate GI (50-70) category, while maize roti (74.70) and maize upma (69.91) were under high GI (70-100) category. Thus the study indicated that the combination of ingredients used as well as the method of cooking had significant influence on GI of the products.

V-2. QUALITY PROTEIN MAIZE (QPM) BASED SNACK FOOD- "CRISPIES" ENRICHED WITH MICRONUTRIENTS

Shobha[1] D., Mahadevu P.[1] and Phagna R.[2]
[1]AICRP on Maize, Zonal Agricultural Research Station, V.C. Farm, Mandya
[2]ICAR-Indian Institute of Maize Research, Ludhiana
shobhafsn@gmail.com

Maize (*Zea mays* L) is the third most important cereal in India, after Rice and Wheat. An attempt was made at the AICRP (Maize), ZARS, Mandya to test the feasibility of maize flour incorporation along with other ingredients in crispies preparation and its impact on quality of crispies in terms of nutritional, sensory and storage behavior was assessed. Different levels of maize flour *viz*., 50, 60, 70 % levels were tried along with other ingredients. Nutritional composition of the developed crispies was analyzed by standard methods. Samples were packed in two types of packaging materials i.e

LDPE covers and Alluminium covers (alluminium cover + one tensil polyester 3 layer film) for a period of 30 days to analyse moisture, peroxide valueand free fatty acids. The overall acceptability scores of crispies prepared by incorporating maize flour at 50 % scored between very good to excellent (4.2) with a textural value of 3.8 along with taste value of 4.10 indicating that crispies were acceptable in terms of sensory parameters. The developed crispies contained 18.18 % protein, 35.20 % fat with a energy content of 564 K cal/ 100 g. The peroxide value was significantly increased from 2.40 to 7.00 and 2.0 to 2.33 to 8.25 in Alluminium packs and LDPE covers respectively over 15 days of storage period. The moisture changes during storage period were 1.39 to 2.08and 1.38 to 2.89 in aluminum covers and LDPE pouches respectively. Hence the study revealed that the crispies from maize were found to be acceptable in terms of sensory, nutritional and storage quality and kept up to 15 days at room temperature without affecting its organoleptic quality.

V-3. DEVELOPMENT OF NUTRITIONALLY ENRICHED GLUTEN FREE PASTA USING QUALITY PROTEIN MAIZE (QPM)

Kambalimatha V.[2], Shobha D.[1], Joshi N.[2] and Phagna R.K.[3]

[1] AICRP on Maize, Zonal Agricultural Research Station, V.C. Farm, Mandya

[2] Department of Food Science and Nutrition, Gandhi Krishi Vigyana Kendra, Bengaluru

[3]ICAR-Indian Institute of Maize Research, Ludhiana

shobhafsn@gmail.com

Pasta is a popular convenience food worldwide, prepared from durum wheat or rice using extrusion cooking. In recent years people allergic to gluten (Celiac disease) are increasing and food products devoid of gluten protein are beneficial to such people with variation in their diet without gluten. Maize is a good source of starch (65-70%), protein (8-10%), fat (3-4%) and some of the important vitamins and minerals and is devoid of gluten protein. The Quality Protein Maize (QPM) has got special distinction among the cereals due to presence of high amount of two essential amino acids viz., lysine and tryptophan with better amino acid balance, hence can be used in diversified ways. Gluten free pasta was developed using QPM(Q), black gram(B) and soya flour(S) in different proportions (T1;Q:B:S-50:30:20, T2;Q:B:S-60:30:10, T3;Q:B-70:30, T4;Q:B-80:20), while control pasta was prepared with wheat (100 %). The extrusion process was performed using single screw extruder (Dolly Pasta Extruder-P3 model). Organoleptic characteristics such as color, appearance, texture, taste, flavorand overall acceptability were evaluated by a panel of semi trained judges using 9 point hedonic rating scale. Among the various blends studied, the QPM, black gram and soya flour combination of 60:30:10 (T2) had better acceptance when compared to other combinations tested. Further, pasta (T2) was also enriched with the addition of spirulina powder at different levels (2, 4, 6, 8 and 10 %) to enhance the sensorial and nutritional quality (Spirulina contains 70% protein, with all essential amino acids, 15–20 % carbohydrates, β-carotene, vitamin B_1,B2,B3, iron, calcium, phenolic acids and tocopherols). The sensory attributes such as color (7.4), appearance (7.5), texture (7.5), flavor (7.4), taste (7.6), stickiness (7.4), bulkiness (7.4), firmness (7.5) and overall acceptability (7.6) were significantly higher for 6 % spirulina incorporated QPM pasta. Incorporation of spirulina powder resulted in nutritionally rich pasta as compared to control (wheat pasta) due to increased nutrient content viz., protein (15.6g/100g), calcium (37.2 mg/100g), iron (5mg/100g), magnesium (144.9 mg/100g)and potassium

(625.9 mg /100g) with a carbohydrate and energy content of 59 % and 323 k cal/100g, respectively.

V-4. MECHANIZED MAIZE CULTIVATION OPTIONS FOR SMALL FARMERS

Bamboriya J.S.[1], Bamboriya S.D.[2] and Dhayal B.L.[3]
[1]Rajasthan College of Agriculture, Maharana Pratap University of Agriculture and Technology, Udaipur
[2]ICAR-Indian Institute of Maize Research, Ludhiana
[3]Chaudhary Charan Singh Haryana Agricultural University, Hisar

Mechanization is application of machine power instead of draught animals or human labour to complete different agricultural tasks. It increases the speed and saves time and labour in farming operations. It lowers production cost and improves farm income. Maize being a wide spaced crop, allow tractor based intercultural and weeding operations. Hybrid seed cultivation is quite common in maize. Hybrids has uniform seed and plant type which germinates and grows together and matures at once which suits seed to seed mechanization. Maize is predominantly (75%) grown as rain fed crop where operations like sowing, weeding, earthing up etc. are all dependent on the rainfall conditions which provided little window period to perform all these operations. Hence, mechanized cultivation will help in doing these critical operations in no time and will reduce drudgery and enhance farm profitability of rain fed maize. Further, the declining trend of labour in agriculture sector also highlighted the need of farm mechanization. Animal drawn ridge maker, cutivator and harrow for seed bed preparation; naveen dibbler, rotary dibbler, one row seed cum ferti drill, metallic tip dibbler, animal drawn multi-crop planter for seeding; serrated sickle for harvesting; tubular/octagonal, rotary type, pedal operated maize sheller etc. are some affordable equipment for small maize farmers. Two wheeled tractor with different attachments can also fulfill multiple field tasks like land preparation, planting, inter cultivation, spraying, harvesting, transportation etc and are also cheaper and affordable by small farmers. Further, custom hiring of larger and costly farm machinery (laser land leveller, pneumatic planter, combine harvester, maize thresher silo pack machine etc.) is another viable option for large scale farm mechanization among small farmers.

V-5. MAIZE ANTHOCYANINS: A POTENTIAL SOURCE FOR NUTRITION AND FORMULATION OF NOVEL FUNCTIONAL FOOD

Bhushan B., Dagla M.C., Dhir A., Chaudhary D.P.
ICAR-Indian Institute of Maize Research, Ludhiana
bharat.bhushan@icar.gov.in

The maize crop is well known for its commercial usage around the world. India is also focussing on its popularization through the development of quality based inbreds or hybrids. The market or saleable quality of food is dictated mainly by the color. The color food not only increases the appeal of a food item but its various shades are being fascinated towards a large population. The anthocyanins are water soluble pigments which are receiving more prominence not only for their colorant properties but also to their antioxidant potential. In order to develop functional food at IIMR, a total of 18 exotic entries including few inbreds and selected maize germplasm from NBPGR were screened for total anthocyanin content. The selection of inbreds was based on high yield potential and color types. The major drawback of usage of anthocyanin is its stability in the basic food items. To overcome this, there is a need to assess the genotypes having maximum anthocyanin content for stability attribute either through composites or nanotechnological interventions.

V-6. STANDARDIZATION AND EVALUATION OF GRAIN STAINING TECHNIQUES IN MAIZE FOR RAPID SCREENING OF IRON AND ZINC CONTENT USING

Sharma D., Pal R. S, Khulbe R. K, Pattanayak A.and Kant L.
ICAR-Vivekananda Parvatiya Krishi AnusandhanSansthan, Almora
devender.kumar1@icar.gov.in

Micronutrient malnutrition is the major problem in developing country affecting billions of people worldwide. Biofortification of crops is the important strategy for combating the malnutrition problem. Maize is the third most important staple food crop consumed worldwide by billions of people directly or indirectly. A great extent of genetic diversity present in the available germplasm for iron (Fe) and zinc (Zn) micronutrient content. Screening of the germplasm for high Fe and Zn content using Atomic Absorption Spectrophotometery (AAS) or Inductively Coupled Plasma Mass Spectrometry (ICP-MS) is costly and time consuming. Though these analytical techniques produce results with great precision, alternative methods are required for screening of a large number of germplasm lines in short period of time. Keeping this in view, in the present investigation a rapid staining method was followed and standardized for screening a set of 33 maize genotypes for Fe and Zn content in the grain. Perl's Prussian Blue and Dithizone (DTZ: 1, 5-diphenyl thiocarbazone) were used as reagents for Fe and Zn, respectively. The intensity of color developed was visually scored as 1, 2 and 3 for high, medium and low micronutrient content, respectively. The reliability and effectiveness of the staining method was tested through correlation analysis between dye staining score and AAS values. The staining score was significantly ($P < 0.05$) associated with the AAS values of Fe ($r=0.55^{**}$) and Zn ($r=0.63^{**}$) which was further confirmed through t-test. The AAS analysis results were in strong congruence with the dye staining method. The genotype VLQC-8(1) was found to have highest level of iron (46.60 mg/kg) andCS-16-2-1had highest level of zinc (30.10 mg/kg) among the genotypes assayed. Besides these, genotypesBS-21-2-3-1, VLQC-1(2), CML 169, CM 212 and V 336 were found to be having considerably higher levels of iron and zinc in the grains. These lines may be used directly for developing hybrids with higher Fe and Zn content or suitable combinations of these lines may be used as source populations for deriving lines with high levels of Fe and Zn through conventional methods or use of molecular markers in combination with double haploid technology. In the present investigation, the colour intensity scores were found to be reliable indicators for grain Fe and Zn content and, the grain-staining technique could, therefore, be effectively used as an initial screening tool for identification of high Fe and Zn genotypesin large genotype sets in a short period of time.

Theme-VI

Sustainable Livestock Industry - Maize a Key Player

VI-1. PERFORMANCE OF MAIZE HYBRIDS FOR FODDER AND GRAIN YIELD DURING SPRING SEASON

Kamboj M.C, Sharma P., Singh N., Jangid K. and Kumar P.
Chaudhary Charan Singh Haryana Agricultural University, Regional Research Station, Karnal

The Indian farmers are dependent upon two major enterprises; crops and livestock for maximizing their family income. Livestock production is the backbone of Indian agriculture contributing 5.4% to National GDP and a source of employment and ultimate livelihood for 70% of the population in rural areas. The milk production in India is 176.3 million tonnes (2017-18), the highest in the world. The milk production to a large extent depends upon the availability of good quality fodder. To meet out the needs of the good quality fodder the production as well productivity of fodder is to be increased by cultivating it at limited area. Green forages are rich and cheapest source of carbohydrates, protein, vitamins and minerals for dairy animals. By providing sufficient quantities of fodder instead of costly concentrates and feeds to the milk animals, the cost of milk production can considerably be reduced. Due to increase in cost of cultivation of cereal and cash crops the fodder production has been decreased. At present, the country faces a net deficit of approximate 61.1% green fodder, 21.9% dry crop residues and 64% concentrate feeds. To meet the current level of livestock production maize can be best solution as fodder. So, the cost of milk production can considerably be reduced by substituting high quality forages for concentrate. Moreover, the nutrients from the fodders are not only easily digestible but palatable also as compared to the nutrients from concentrates. Maize is one of the most versatile emerging crops having wider adaptability under varied agro-climatic conditions. As it has higher potential for grain and fodder yield than any other cereal, it is sometimes referred to as the miracle crop or the 'Queen of Cereals'. It is the crop which may be grown throughout the country in all season and is also best as silage crop. The cost of seed production of single cross hybrids is very high as compared to three way crosses and that is why the seed of public sector hybrids is not available to the farmers. Keeping these problems in mind eighteen hybrids (eight single cross and ten three way crosses) were evaluated for grain yield and fodder yield, days to dough stage , tryptophan per cent and other important agronomic traits during Spring 2019 at CCS HAU Regional Research Station Farm, Karnal. Among the single cross hybrids HQPM 4 gave maximum fodder yield (508.2 q/ha) followed by HM 10 (502.4 q/ha) while among the three way crosses HM 10 × HKI 161 gave maximum fodder yield (501.3 q/ha) followed by (HKI 193-2 x HKI 163) × HKI 161 (496.8 q/ha) and HQPM 5 × HKI 193-2 (490.7 q/ha). Maximum grain yield was observed in HM 11 (70.2 q/ha) followed by HM 10 (69.4 q/ha), HQPM 4 (68.2 q/ha) among the single cross hybrids while among three way crosses maximum grain yield was found in (HKI 193-2 × HKI 163) × HKI 161 (69.6 q/ha) followed by (HKI 170 x HKI 193-2) x HKI 161 (69.1 q/ha) and HQPM 5 × 193-2 (68.4 q/ha). Days to dough stage varied from 101 days (HM 8, HM 9 and HM 9 x HKI 163) to 107 days (HM 10, HM 11, HQPM 4, (HKI 193-2 ×HKI 163) x HKI 161, The tryptophan content varied from 0.41 per cent (HM 8) to 0.77 per cent (HQPM 4). Among all the hybrids tested HQPM 4 was found best for fodder and silage as it is having maximum fodder yield (508.2 q/ha), with 0.77 per cent tryptophan followed by two three way crosses (HKI 193-2 × 163) × HKI 161 (fodder yield: 496.8 q/ha, tryptophan: 0.71 per cent) and HQPM 5 × HKI 193-2 (fodder yield: 490.7 q/ha and tryptophan: 0.76 per cent). These two three way crosses may be used for fodder and silage purpose after multi location testing.

VI-2. ASSESSMENT OF GENETIC DIVERSITY AND ITS RELATIONSHIP WITH HETEROSIS FOR FORAGE TRAITS IN MAIZE (*ZEA MAYS* L.)

Doggalli G., Mahadevu P., Lohithaswa H.C., Shekar B.G. and Mallikarjuna N.
Zonal Agricultural Research Station, V. C. Farm, Mandya
University of Agricultural sciences, Bangalore

An investigation was carried out to estimate the genetic diversity, combining ability and to assess the relationship between parental diversity and heterosis in newly developed inbred lines for forage traits in maize (Zea mays L.) at the Zonal Agricultural Research Station, V. C. Farm, Mandya and Main Research Station, Hebbal during 2018-19. Fifty inbred lines were grouped in to seven clusters using Mahalanobis D2 statistic. The cluster II composed of maximum number of inbred lines (18) followed by cluster III (14). Combining ability analysis was performed using 50 lines and four testers by employing Line × Tester mating design. The ratio of GCA to SCA variance revealed the preponderance of non-additive gene action in the expression of all the traits under study. The lines viz., 1-50-7, 1-63-5 and 1-17-19 in E1;1-17-19, 5-6-1 and 1-50-7 in E2; 1-50-7, HCL-7 and 2-4-1-2 and tester CAL-1443 were identified as best general combiners for forage yield and yield related characters. Among crosses, 1-5-12 × VL121096, 1-17-19 × CAL-1443, 1-19-5 × CAL-1443, MAI-179 × VL108867, 1-44-9 × CM-202, 1-50-7 × CM-202, 1-63-5 × CAL-1443 and 5-12-1-1 × CAL-1443 exhibited highest significant sca effects and high heterosis over checks for green forage yield. The parents were grouped into four classes based on mean and standard deviation of D2 values and found that maximum number of heterotic crosses resulted from parents included in medium divergence classes. The 200 hybrids, 50 inbred lines and four testers along with two standard checks (CM-202 and Nithyashree) were evaluated for their reaction to Turcicum leaf blight. Out of 200 hybrids, 98 hybrids showed resistance and 58 were moderately resistant. Among 54 parents, 26 lines showed resistant reaction, 12 lines showed moderate resistance, 10 lines were moderately susceptible and six lines recorded susceptible reaction.

VI-3. PERFORMANCE OF FODDER MAIZE GENOTYPES FOR HIGHER GREEN FORAGE YIELD AND QUALITY IN SOUTHERN DRY ZONE OF KARNATAKA

Mahadevu P., Shekara B.G., Chikuragi N.and Manasa N.
AICRP on Forage crops and utilization, Zonal Agricultural Research Station, Mandya

An experiment was conducted at Zonal Agricultural Research Station, V.C.Farm, Mandya during kharif 2019 to identify fodder maize genotypes having higher green forage yield and quality suitable for southern dry zone of karnataka. Among the genotypes evaluated, J-1006 recorded highest mean green forage yield of 475.6 q/ha as compared to other entries. However, the genotypes TSFM 15-5 and CO HM 8 found superior with higher crude protein percentage (9.2%) and crude protein yield (9.3 q/ha) respectively as compared to other genotypes and checks. CO HM- 8 also recorded higher dry matter yield of 131.7 q/ha followed by ADV 6737 (109.3 q/ha) as compared to all other genotypes.

Theme-VII

Innovative Marketing Linkages for Profitability in Maize - Way Forward

VII-1. TRANSFER OF TECHNOLOGY AND SKILL TRAINING PROGRAMMES TO PROMOTE MAIZE BASED ENTREPRENEURSHIP

Shobha D., Puttramnaik and Mahadevu P.
AICRP on Maize, Zonal Agricultural Research Station, V.C. Farm, Mandya
shobhafsn@gmail.com

Value addition to maize is important to make maize a nutritionally enriched and acceptable grain. The Quality Protein Maize (QPM) which has better amino acid balance can be utilized in diversified ways. Technologies developed at AICRP (Maize) like lime treatment of grains, milling, extrusion enrichment with other ingredients and enhancing their palatability through standardization process have been adopted to make maize a viable ingredient for value addition. Maize processing unit established at AICRP (Maize), Mandya has plant and machinery such as dry mill, papad maker, noodle making machine, pasta unit, dryer and pop corn maker were made use of in the production of flour, semolina, papad, pasta, vermicelli, crispies and RTC products such as nutri mix, idli mix and vada mix from maize . Around 250 SHG women and small entrepreneurs were trained in the processing, value addition, packing and marketing of the products. Commercially the maize value added products were sold by an entrepreneur Mr Aaaradhya of Aaradhya Agro Food and Beverages, Mysore under the brand name "Maizy". The nutritious products of QPM can replace fancied and highly priced industrial foods. These products can also be prepared in villages with minimum machinery and could be great source of rural entrepreneurship. Thus QPM based rural industries have a wider scope for employment generation and rural prosperity.

VII-2. PRODUCTIVITY AND ECONOMIC FEASIBILITY OF MAIZE (*ZEA MAYS*, VAR. SHALIMAR MAIZE COMPOSITE-6) AS AFFECTED BY DIFFERENT TILLAGE METHODS AND SOWING TIME UNDER TEMPERATE CONDITIONS OF KASHMIR.

Yousuf W., Qayoom S., Ahmad B., Ahmad L. and Mushtaq N.
Division of Agronomy,
Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir

A field experiment was conducted at Crop Research Farm Faculty of Agriculture, Wadura, during kharif 2017 and 2018 on a clay loam soil, to study theEffect of tillage methods and sowing time on productivity and economics of maize,(*Zea mays* , var. Shalimar Maize Composite-6) under temperate conditions. The experiment comprising of 12 treatment combinations viz., 3 tillage methods (minimum tillage, ridge bed sowing and conventional tillage)and 4 dates of sowing ($20^{th,}$ 21^{st} 22^{nd} and 23^{rd} meteorological standard week, was laid out in a strip plot design with three replications. The results revealed that grain yield (46.70qha^{-1}) and stover yield (69.12qha-^{1}) of maize increased significantly for maize sown in 20^{th} standard meteorological week with concomitant increase in its yield attributes and growth characters. The minimum tillage resulted in significantly higher grain (45.38 qha^{-1}) and stover yield (65.73 qha^{-1}) of maize along with all the growth and yield attributing characters studied. The highest benefit:cost ratio of ₹ 2.2and net profit of **₹79873.6** was recorded with treatment combination of maize sown in 20^{th} standard meteorological week and minimum tillage, hence this treatment combination was recommended for obtaining most profitable grain yield of maize.

Author Index


RALLIS INDIA LI
A TATA Enter
Dhaanya SEEDS
Progress Through Technology
SCIENCE & DETERMINATION.
THE PERFECT COMBINATION
DMH8255
MM1107
MM9333