

Souvenir

National Workshop and
Brainstorming Session on

UNLEASHING THE HIDDEN POTENTIAL OF MAIZE TECHNOLOGY IN NEH REGION : STATUS, OPTIONS AND STRATEGIES

30-31 July, 2018
Imphal, Manipur



Organized By -

ICAR Research Complex for NEH Region
Umiam, Meghalaya

ICAR-Indian Institute of Maize Research
Ludhiana, Punjab

Co-sponsored By -

National Bank for Agriculture and Rural Development
Manipur Regional Office, Imphal

Souvenir

NATIONAL WORKSHOP CUM BRAINSTORMING ON UNLEASHING THE HIDDEN POTENTIAL OF MAIZE TECHNOLOGY IN NEH REGION: STATUS, OPTIONS AND STRATEGIES

**30th AND 31ST JULY, 2018
IMPHAL, MANIPUR**



Organized by

**ICAR RESEARCH COMPLEX FOR NEH REGION, UMROI ROAD,
UMIAM, MEGHALAYA- 793103
ICAR-INDIAN INSTITUTE OF MAIZE RESEARCH, PAU CAMPUS,
LUDHIANA, PUNJAB- - 141004**

Souvenir

NATIONAL WORKSHOP CUM BRAINSTORMING ON UNLEASHING THE HIDDEN POTENTIAL OF MAIZE TECHNOLOGY IN NEH REGION: STATUS, OPTIONS AND STRATEGIES

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JULY, 2018

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Dr. NAJMA HEPTULLA
Governor of Manipur



डा. नजमा हेपतुल्ला
राज्यपाल, मणिपुर



Message

I am very happy to learn that ICAR Research Complex for North East Himalayan Region, Umroi Road, Meghalaya in collaboration with ICAR- Indian Institute of Maize Research, PAU Campus, Ludhiana, Punjab as prime sponsor is organizing a 2-Day National Workshop-cum-Brainstorming Session on “Unleashing the hidden potential of maize technology in NEH Region: Status, Option and Strategies” from July 30-31, 2018 at Imphal and a Souvenir is being brought out to commemorate the event.

Maize is considered the third important cereal crop in the world after wheat and rice and the most important emerging crop in the Eastern Himalayan Region. However, the average productivity in Manipur is still below the national average and there is urgent need of addressing the farmer's requirement for enhancement of its productivity. Popularization of improved technologies of maize to a particular agro-ecological condition is an utmost priority to tap the hidden productivity potential. High yielding varieties (HYV) of maize are widely adopted in other parts of the country, but most of the farmers in this region are growing low yielding local varieties, less adaptive to changing climate, particularly rainfall and temperature trend. It is anticipated that HYVs of maize with better management practices have immense potential to increase the existing production level by 2-3 times in the hilly ecosystem of the region.

It is heartening to learn that many eminent scientists, academicians, extension functionaries, State officials, agro-industries, students from across the country and more than 100 progressive farmers will be participating in this event. I am fully confident that the workshop will provide the platform for exchange of valuable ideas among the resource persons and the farmers will be better equipped to increase maize production and better sustain their livelihood.

I wish the National Workshop a grand success.

Najma Heptulla
(Najma Heptulla)
Governor of Manipur



सत्यमेव जयते

**CHIEF MINISTER
MANIPUR**



Message

It give me immense pleasure to learn that ICAR Research Complex for NEH Region, Umiam (Meghalaya) in association with ICAR – Indian Institute of Maize Research, PAU Campus, Ludhiana (Punjab) is organizing a National Workshop cum Brainstorming Session on the topic, “Unleashing the hidden potential of maize technology in NEH Region: Status, Option and Strategies” during July 30th – 31st, 2018 at Imphal and that, a souvenir is being brought out to mark the occasion.

Food security is a thrust area of the Government and enhancement in maize production through introduction of new technology will play significant part in ensuring food security.

I am hopeful that the workshop will be able to conceive strategies to introduce new technologies for large scale cultivation of maize in sustainable manner in the North East region.

I wish the workshop and souvenir a grand success.

(N. Biren Singh)

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सत्यमेव जयते



Message

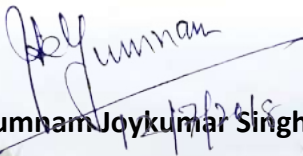
I am glad to learn that the ICAR Research Complex for NEH Region, Meghalaya and ICAR Indian Institute of Maize Research, PAU Campus, Ludhiana are jointly organizing a National Workshop cum Brainstorming Session on “Unleashing the hidden potential of maize technology in NEH Region: status, options and strategies” during 30th to 31st July, 2018 at Imphal, Manipur.

Climatic conditions apart from soil composition play great importance for successful cultivation of agricultural crops especially maize. The phenomenon of climatic change in the recent years has serious and far reaching impact on agriculture. For these reasons, a national level workshop on effect of climatic change and prevailing soil composition in the North East Region and how these can be controlled and handled to optimize agricultural produce is a must.

In this region, apart from rice, the main crop grown, maize production plays a significant role in ensuring food security as the same is used both for direct consumption as well as feed for animals and poultry. However, unfortunately, the average yield and productivity in this region is very low compared to the National average. This low productivity is attributed to many regions like adoption of traditional low yielding genotype, poor knowledge of soil chemistry, erratic distribution of rainfall resulting to water scarcity etc. Lack of proper irrigation system is yet another factor in this regard.

I am sure that the National Workshop will cover all these aspects in their deliberation and bring out suitable solution apart from enlightening the farmers of the region.

Let me also convey my best wishes to the organizers and wish a grand success to this National Workshop.


(Yumnam Joykumar Singh)

V. HANGKHANLIAN
MINISTER (AGRI/VETY)
MANIPUR



सत्यमेव जयते



Message

I am glad to know that the ICAR Research Complex for NEH Region, Meghalaya and Indian Institute of Maize Research, PAU Campus, Ludhiana, Punjab are jointly organizing a National Workshop cum Brainstorming Session on “Unleashing the hidden potential of maize technology in NEH Region: status, options and strategies” during 30th to 31st July, 2018 at Imphal, Manipur.

I congratulate the organizing committee for the sincere effort to take up the noble task of organizing such an important seminar in the state of Manipur. This will undoubtedly open up opportunities for the region to tap its immense potential of maize in agricultural production. This National workshop is a welcome step to congregate a large number of researchers, extension workers, policy planners, agro-industries, marketing agencies, NGOs and progressive farmers to brainstorm, discuss and conceptualize a meaningful strategy pertaining to agricultural development in the North East Region in particular and the country at large in the context of changing climate.

I extend my best compliments to ICAR and wish the seminar a grand success.

V. Hangkhanlian
(V. Hangkhanlian)



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Message

I am immensely happy to learn that the ICAR Research Complex for NEH Region, Umroi Road, Umiam, Meghalaya and ICAR- Indian Institute of Maize Research, PAU campus, Ludhiana, Punjab are jointly organising a two days National Workshop cum Brainstorming Session on "Unleashing the Hidden Potential of Maize Technology in NEH Region: status, option and strategies" during 30th- 31st July, 2018 at ICAR, Manipur Centre, Lamphelpat, Imphal and a Souvenir is being brought to commemorate the occasion. The theme chosen for the conference is of topical interest. In the uplands of the North Eastern Hill Region of India, rainfed maize is the second most important crop and occupies considerable area. Cost of maize is very high since it is an ingredient for feeds of animal, fish, poultry etc. and it is the most emerging crop in the region. However, the average productivity of maize in the region is very low ($<2.0 \text{ ton ha}^{-1}$) as compared to average productivity of India (2.43 ton^{-1}). Hence, there is an urgent need of addressing the farmer's requirement for enhancement of their productivity. Under the present scenario, attention is required to be given not only to technological backup, but also to make roadmap for technologies transformation to the farmer's field along with strengthening in post harvest and value addition.

It is of great significance that this august body is going to deliberate upon several important topics, including status, scope, constraints, strategies and recent scientific advances in the field of improved technology of maize production suitable for the North Eastern India covering all the stakeholders. I am sure that the deliberations made at the workshop cum brainstorming session will immensely help in increasing maize production and also, improve the income of the farmer's in the NEH region. I wish the organizers and the participants of the workshop a grand success.



(M. Premjit Singh)

LETKHOGIN HAOKIP, IAS
Additional Chief Secretary
Government of Manipur



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Message

I am happy to learn that ICAR Research Complex for NEH Region, Meghalaya and Indian Institute of Maize Research, PAU Campus, Ludhiana, Punjab is organizing a National Workshop cum Brainstorming Session on “Unleashing the hidden potential of maize technology in NEH Region: status, options and strategies” during 30th to 31st July, 2018 at Imphal, Manipur.

We need to double maize production and productivity in NEH Region through multi-institutional, multi-pronged strategies. This can be achieved through germplasm enhancement, broadening the phenotyping scale and precision among other improved technologies and management practices. Popularization of improved technologies of maize to a particular agro-ecological condition is at utmost priority for getting potential productivity and exploring hidden potential of maize in this region.

I earnestly hope that this National Workshop would bring out the critical issues confronting the farming community of the NEH region in context of the agricultural production and suggest appropriate strategies to accomplish the mission of livelihood security through sustainable farming practices.

I wish the Workshop all success.



(Letkhogin Haokip)



PH. RAJENDRA SINGH
Director of Agriculture, Manipur

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Message

I am glad to learn that the ICAR Research Complex for NEH Region, Umiam, Meghalaya and ICAR-Indian Institute of Maize Research, PAU Campus, Ludhiana, Punjab is jointly organizing two days National Workshop cum Brainstorming session on “ Unleashing the hidden potential of maize technology in NEH Regions: Status, options and Strategies” on July 30th – 31st, 2018 at Imphal, Manipur.

Maize is the 2nd important cereal crop next to rice in the State of Manipur. This crop is mostly produced by small scale farmers. Now-a-days, Maize has become an important livestock feed both as silage and as crop residue, grain and is also used industrially for starch and oil extraction. The production of maize in the State is highly deficit to meet the requirement of both livestock feed preparation and human consumption.

Increasing of production of maize in the State to meet the requirement becomes the priority sector for increasing production and employment generation. In order to meet the requirement and to exploit the untapped/under tapped resource in the hill areas, massive programme on cultivation of maize with Good Agronomic Practices (GAP) may be conducted in the potential areas.

I hope that this workshop will provide a meaningful strategy for ensuring of sustainable agriculture besides Doubling of Farmers Income by 2022 in the State in particular and in the NEH Region in general.

I wish the organization of National Workshop a grand success.

(Ph. Rajendra Singh)



भारतीय कृषि अनुसन्धान परिषद्
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Message

It is great pleasure for me to learn that ICAR Research Complex for NEH Region, Meghalaya and Indian Institute of Maize Research, PAU Campus, Ludhiana, Punjab are jointly organizing a National Workshop cum Brainstorming Session on “Unleashing the hidden potential of maize technology in NEH Region: status, options and strategies” during 30th to 31st July, 2018 at Imphal, Manipur.

In the North Eastern Himalayan Region (EHR) of India, maize is the second most important crop, next to rice and is mostly grown under foot hills and hilly 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. The average productivity of maize in the region is low as compared to National average maize productivity. We need to double maize production and productivity in NEH Region through multi-institutional, multi-pronged strategies. This can be achieved through germplasm enhancement, broadening the phenotyping scale and precision among other improved technologies and management practices. Quality Protein Maize (QPM) with its high carbohydrates, fats, better quality proteins, some of vitamins and minerals, it is nutritious feed for poultry, livestock, swine, fish, etc. Use of QPM as poultry feed leads to early development of broilers, save energy and feed, and also the extra cost incurred on lysine and tryptophan fortification. Popularization of improved technologies of maize to a particular agro-ecological condition is at utmost priority for getting potential productivity and exploring hidden potential of maize in this region.

I earnestly hope that the outcome of National Workshop would bring out the critical issues confronting the farming community of the NEH region and serve as the guidance force for the farming community, policy makers and other stakeholders. I wish the event at grant success.

(Narendra Prakash)



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Message

It gives me immense pleasure to note that the ICAR Research Complex for NEH Region, Meghalaya in collaboration with ICAR-Indian Institute of Maize Research, Ludhiana organizing a National Workshop cum Brainstorming Session on “Unleashing the hidden potential of maize technology in NEH Region: status, options and strategies” during 30th to 31st July, 2018 at Imphal, Manipur.

Maize being a queen of cereals and grown in all the NEH states have immense potential for its cultivation in this ecologies. The favorable rainfall and high organic matter soil provided good opportunity of the cultivation of this crop in these ecologies by adoption of high yielding maize cultivars specially hybrids that can tolerate biotic and abiotic stresses for providing resilience in the maize systems in NEH states. Despite this, this region is net importer of maize having competitive demands from poultry, piggery, fishery etc. for feed and thus, enhancing production in this ecology will further boost these sectors in this important strategic region of the country.

The cultivation of the specialty corns like baby corn, sweet corn and pop corn have potential for enhancing the profitability of the maize cultivation in this region where land holding is limited with enough work force engaged in agriculture. The establishments of the processing industries for these specialty corns and the feed have potential to further boosting growth of maize in this region. Growing of these specialty corns will also boot up the animal sector growth and will help in realizing the doubling farmer income, the agenda of Government of India. The cultivation of the quality protein maize (QPM) can address the issue of the food, feed and nutritional security of this region.

I am sure that this workshop will be successful in discussing various issues and bringing up strategies to enhance production of maize and its utilization in sustainable manner in this North Eastern Himalayan Region. I am looking forward for the roadmap for maize in NEH region as recommendations in this workshop.

I extend my warm wishes to the organizers for a successful and fruitful event.


(S. Rakshit)



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अल्मोड़ा. २६३ ६०१ (उत्तराखंड)

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Message

I am happy to learn that the National Workshop cum Brainstorming Session on “Unleashing the hidden potential of maize technology in NEH region: status, options and strategies” is being organized on 30-31 July, 2018 at ICAR Complex for NEH Region, Manipur Centre Imphal, Manipur. Maize is an important crop of North Eastern Region with a very high potential for increase in production. The region is also very rich in genetic diversity of maize. The famous Murli maize exists in this region. The technology breakthrough in maize has made it possible to achieve great heights in yield through hybrids. However, the popularity of hybrids in the NEH region is yet to catch-up. I believe that this brain storming session will help to create awareness for the improved maize varieties alongwith their improved agronomic practices. This will help for the co-evolution of maize and piggery industry in the region, which was envisaged long back.

I wish the session a great success in its deliberations.


(A. Pattanayak)

राष्ट्रीय कृषि और ग्रामीण विकास बैंक
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मणिपुर क्षेत्रीय कार्यालय

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I am elated to know that ICAR Research Complex for NEH Region, Meghalaya and Indian Institute of Maize Research, PAU Campus, Ludhiana, Punjab is organizing a National Workshop cum Brainstorming Session on “Unleashing the hidden potential of maize technology in NEH Region: status, options and strategies” during 30th to 31st July, 2018 at Imphal, Manipur.

Maize has shifted from traditional food crop to industrial commodity. Use of maize for food and processed food industries has steadily increased. In recent decade, major maize producing countries reduced their export due to increased domestic demand for ethanol industry. This has affected maize supply in global trade. Substantial progress in maize production has been made in North Eastern Hill Region. The success has been mainly attributed to the adoption of improved technologies resulted from research and development. It is realized that the role of maize workers (researchers, extensions, policy makers and industries) is important in the increased maize production in NEH Region.

Given this background, formulating suitable technologies of maize to increase the productivity of this region is the need of the hour. I feel very proud for the praiseworthy initiatives taken by ICAR Research Complex for NEH Region to organize the workshop.

I wish the Workshop be very successful with great satisfaction.


(P.N. Praveen Kumar)
General Manager/ OIC
NABARD



भारतीय कृषि अनुसंधान परिषद
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From the Desk of Convener

I am very thankful to the Indian Institute of Maize Research, PAU Campus, Ludhiana, Punjab and the ICAR Research Complex for NEH Region, Meghalaya for jointly organizing this two days National Workshop cum Brainstorming Session entitled “Unleashing the hidden potential of Maize Technology in NEH Region: status, options and strategies” during 30th to 31st July, 2018 at Imphal, Manipur at the ICAR RC Manipur Centre, Lamphelpat, Imphal.

In the uplands of the Eastern Himalayan Region (EHR) of India, maize is the second most important crop and occupying considerable area. North Eastern Region of India having a wide number of germplasm is considered to be the Secondary origin of maize. Since, maize is an essential ingredient for feeds of animal, fish, poultry and cost of feed has soothe up very high, its importance is increasing day by day. Thus, maize is the most important emerging crop in the EHR. The average productivity of maize in Manipur is low with less than 2.0 t/ha as against national average of 2.43t/. Thus, there is an urgent need to address the farmers’ requirement for enhancement of their productivity. Under the present scenario, attention is required to be given not only to technological backup, but also to make roadmap for technologies transformation to the farmers’ field along with strengthening in value addition and market chain.

We hope that the Brainstorming cum National Workshop will provide a great opportunity to bring together the multidisciplinary scientific team, academicians, policy makers, line departments, financial institutions, Krishi Vigyan Kendras, NGOs, Students, Farmers, Media and other stakeholders to a common platform for sharing their problems, finding ideas to formulate a fruitful strategies for sustainable way for harnessing the hidden potential of maize production in NEH Region. The recommendations derived out of this event will be published as policy document for sustainable maize production and value addition for the North Eastern Hill Region in particularly for Manipur and for the general.

On behalf of the organizing committee, I extend my heartfelt gratitude to our sponsors, invited speakers, experts, delegates, representative from NGOs, media and specially our farmer friends for their valuable contributions to the workshop. I also thank all the committee members for their sincere efforts in organizing the event successfully. We hope that this two days Brainstorming cum National Workshop will provide an effective stimulus to full fill the ultimate goal to serve the human kind and all forms of the lives on the earth.


(I. Meghachandra Singh)



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From the Desk of NEH Coordinator

It gives me a feeling of joy and pride to share that the ICAR- Indian Institute of Maize Research, PAU Campus, Ludhiana, Punjab sponsor the collaborative programme on Promoting improved technology of maize production in NEH Region to harness the hidden potential of NEH region in doubling the maize productivity. I respectfully appreciate the efforts of ICAR Research Complex for NEH Region, Meghalaya and its Regional Centre for implementation of the said programme in every NEH states and organization of National Workshop cum Brainstorming Session on “Unleashing the hidden potential of maize technology in NEH Region: status, options and strategies” during 30th to 31st July, 2018 at ICAR Research Complex for NEH Region, Manipur Centre, Imphal, Manipur.

In the North Eastern Himalayan Region of India, maize occupies considerable area after rice. Maize production in NEHR is less than national average of maize production and other potential maize growing states. Despite of several problems (Acidic soil, High Rainfall, macro and micronutrients deficiency etc.), NEHR has hidden potential of high maize production (Soil enrich in organic carbon, better biological properties etc.). This is possible only through suitable technological transformation at farmer’s field. In NEHR, poultry, fishery and piggery farming is the prioritized activities, here maize grain may utilized for the second cycle produce and stalk may utilized for cattle. There is also opportunity of value addition through baby corn and sweet corn in NEH Region. Therefore, attention is required to be given not only to technological backup, but also to make roadmap for technologies transformation to the farmer’s field along with strengthening in value addition.

I am very much confident that this National Brainstorming workshop will brings a common platform for sharing their problems, finding and ideas by all the stakeholders and to formulate a meaning strategies for sustainable way for harnessing the hidden potential of maize production in NEH Region.

I am very much thankful to all the esteemed delegates, collaborative partners, participants especially farmers for sharing their views and ides in this National brainstorming Workshop and for harnessing the hidden potential of maize production in NEH Region and societal cause.


(S. L. Jat)



भारतीय कृषि अनुसंधान परिषद
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From the Desk of Organizing Secretary

Maize is a multi-faceted crop used as food, feed and industrial crop globally. Currently this coarse grain is cultivated in about 10.2 Million hectare in India. The increasing interest of the consumers in nutritionally enriched products and rising demand for poultry feed which accounts 47% of total maize consumption are the driving forces behind increasing consumption of Maize in the country. As per the demand estimates, the Indian Maize production has to grow with CAGR of 15% in next 4-5 years. Similarly, In the NEH 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 livestock, piggery and poultry farming. The average productivity of maize in the region is very low ($<1.5 \text{ t ha}^{-1}$) than national average productivity (2.6 tonnes/ha) and other potential maize growing states ($> 4.0 \text{ t ha}^{-1}$ Andhra Pradesh, Karnataka and sometimes from Bihar). In NEHR of Manipur, area under maize cultivation is 26,090 ha with production 58,610 Mt with a productivity of 2.25 Mt/ha.

It is in response to such increasing demand, NEHR needs to plan production by productivity increase and also reorient value chain if it is to serve the basic goal of remunerative prices for farmers. This time the driver of change is surge in demand for Maize from Maize based businesses, be it poultry, feed, starch or processed food. High yielding varieties (HYV) of maize widely adopted in other parts of country, but in the NEHR, most of the farmers are growing low yielding local genotypes. It is anticipated that HYVs of maize with better management practices have immense potential to increase the existing production level by 2-3 times in the hilly ecosystem of NEHR. To achieve sustainable double maize yield and enhance the farmer's income five pillars move together Linkage and aggregation with all stakeholders, enabling infrastructure at grassroots level, forging PPP, Policy framework and technological intervention.

In this backdrop, objective of the National Workshop cum Brainstorming on "Unleashing the hidden potential of maize technology in NEH Region: status, options and strategies" is to create awareness among various stakeholders of agriculture especially farmers, policy makers and to identify possible reasons for low productivity of maize through participatory interaction. All researchers, policy makers, extension functionaries and farmers come together and put forth all ideation, deliberate and brainstorming to bring out the sustainable, feasible and acceptable strategies to for the doubling of the maize production and farmer's net income with harnessing the hidden potential of maize production in NEH Region.

The organizers are highly grateful to all the esteemed delegates, collaborative partners, participants especially farmers for making it possible to attend the National brainstorming Workshop and extending their contributions wholeheartedly for science and societal cause.


(M. A. Ansari)

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STATUS, POTENTIAL AND PRODUCTION STRATEGIES FOR MAIZE IN SIKKIM HIMALAYAS

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The North Eastern region of India is blessed with the unique biodiversity and Sikkim is the one of the biodiversity hotspot in the North Eastern Himalayas (Sharma *et al.*, 2016). The agrodiversity of Sikkim can be categorized into four prominent systems covering diverse ecosystems between elevations of 300 and 5,500 m *i.e.*, pastoralism/agropastoralism in the alpine and trans-Himalayan zones (4,000-5,500 m), mixed farming (subsistence agriculture) in the temperate zones (2,500-4,000 m), traditional agroforestry systems in the subtropical to warm temperate zones (600-2,500 m), terrace rice cultivation-based mixed farming in the subtropical zone (above 300 m). Agriculture is the main source of livelihood for more than 75% of the population of Sikkim and contributes around 17% to the gross state domestic product. Agriculture in Sikkim was organic by default, crops are grown in traditional way *i.e.*, the organic practices, however, officially the state has been declared organic from 2003 and attained fully organic status by December 2015 (Bhutia *et al.*, 2016). Due to wide range of altitude (300 to 5000 msl), the Sikkim hills possess a wide range of agroclimatic conditions.

Maize (*Zea mays* L.) is main cereal crop of the world after wheat and rice with wider adaptability under different agro-climatic conditions. Worldwide, it is known as queen of cereals because of its higher genetic potential. It is an important food crop of the North East India. It is the most significant cereal crop of Sikkim locally known as 'Makai'. In Sikkim, it is grown over area of 38960 ha with a production and productivity of 68310 tonnes and 1753.56 kg/ha, respectively (Anonymous, 2015). In Sikkim, versatile uses of maize have been under practice over the years. Maize grains are broken into small pieces and consumed as rice (*makkai kochamal*), The green cobs are consumed extensively as roasted and steamed. It is being used as main ingredient of various local snack products like *chewra*, *sattu* etc. It is importantly used as animal feed, decorative items, and in other miscellaneous practices (Borah *et al.*, 2012).

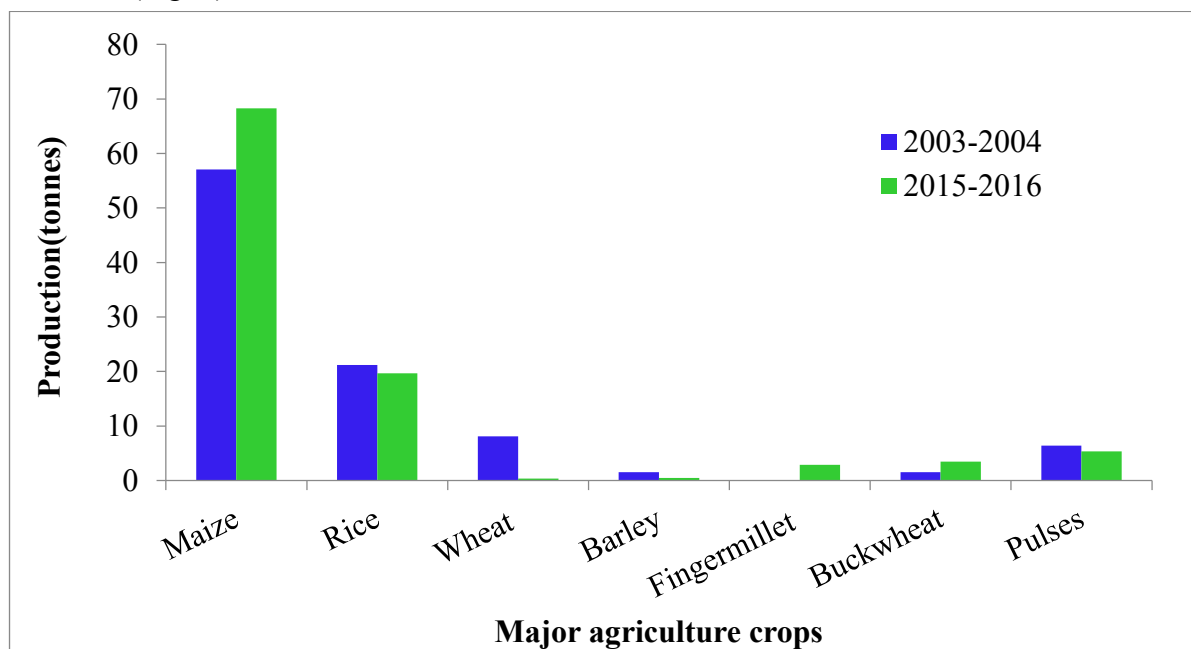
Sikkim seems to be secondary centre of origin of maize with pool of immensely diverse landraces. The maize-based systems are being focused due to its sustainability and economic profitability. Its potential is evident in many cropping systems adopted in this region. In Sikkim, maize is extensively grown in the altitude ranging from 300 to 2200 m msl with more than 80 per cent in the mid-hills. It is sown in the *pre-Kharif* season starting from Feb to mid-March. Due to water scarcity during the *Rabi* season, majority of the farmers are naturally forced to follow maize-fallow rotation production (Basnet *et al.*, 2003). Therefore, the resource poor farmers are not able to sustain their livelihoods. The maize crop is nutrient exhaustive crop and being an organic production region maintainance of the soil fertility solely depends upon the organic

nutrient management. The productivity is far below the national average due to rainfed cultivation and predominance of low yielding local cultivars. The yield mainly decreases with increase in the altitude, which can be attributed to lack of location specific varieties, inadequate use of organic manure and unfavorable climatic conditions like heavy rain with hailstorms that are common (Singh *et al.*, 2012).

The area under the traditional maize cultivation is slowly transforming towards the improved organic farming practices. In this paper, the authors present and discuss the status and scope of organic maize cultivation, production constraints and strategies for productivity improvement in the Sikkim Himalayas.

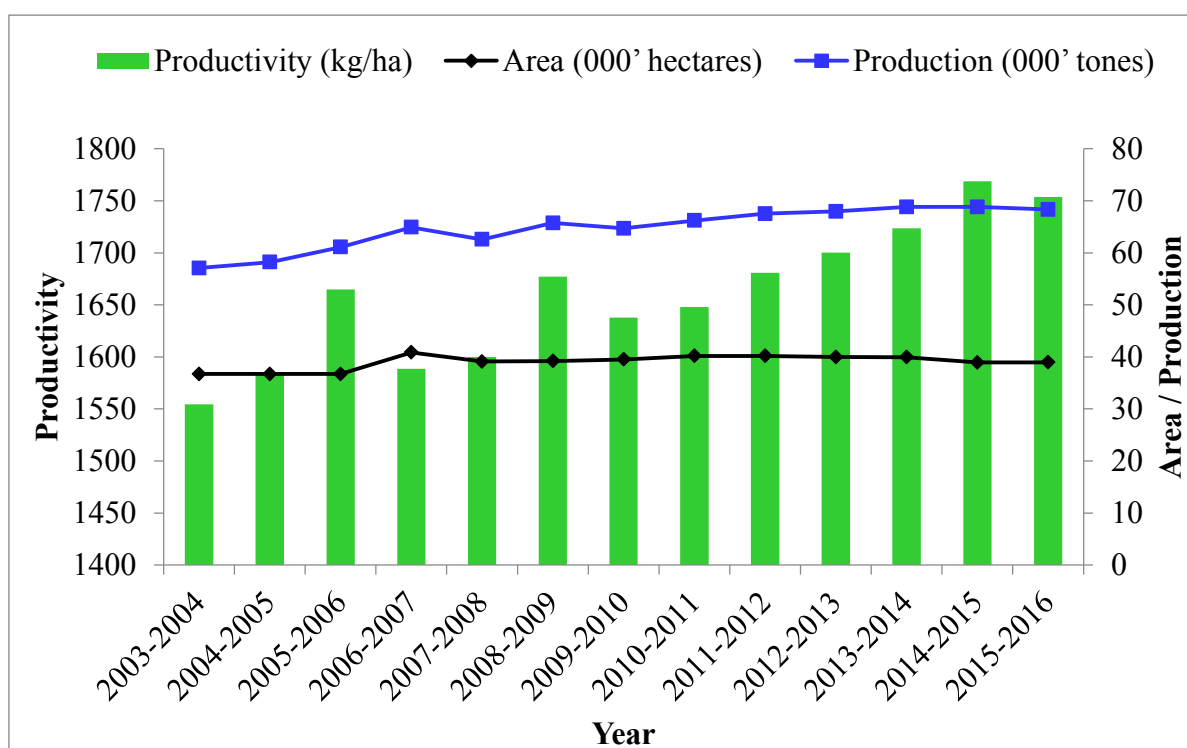
Maize production scenario in Sikkim

The agriculture crop production in Sikkim significantly increased with a maximum share of maize followed by rice and the remaining share being taken by the other crops (Fig. 1). The area under maize crop increased over the last few years in the NEH from 36700 ha in 2003-04 to about 38960 ha in 2015-16 (Fig.2). The productivity of maize during this period also enhanced from 1554.5 to 1753.56 kg/ha. According to Anonymous (2015), among the four districts of Sikkim, South Sikkim has the highest area under maize cultivation (14.31 thousand ha) with productivity of 1761.01 kg/ha. North Sikkim is lagging behind in this regard as compared to the all districts (Fig. 3).



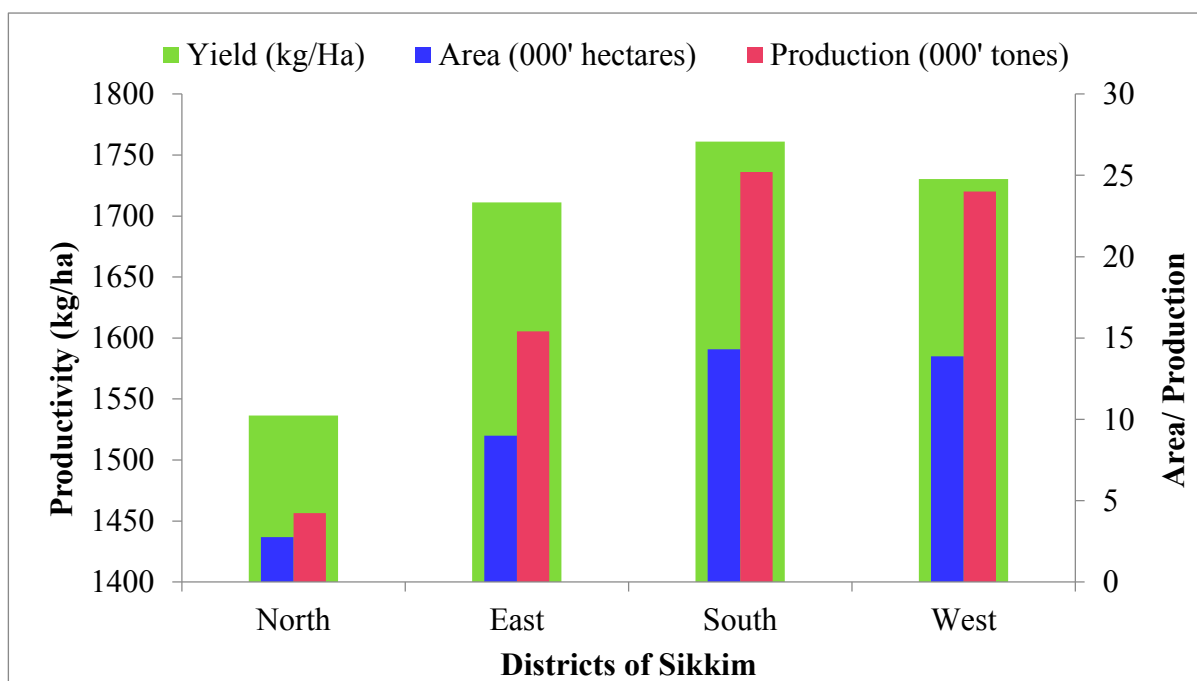
Data source: Anonymous (2018) ENVIS Centre: Sikkim Status of Environment and Related Issues.

Figure 1. Agriculture crop production in Sikkim



Data source: Anonymous (2018) ENVIS Centre: Sikkim Status of Environment and Related Issues

Figure 2. Trend in area, production and productivity of Maize in Sikkim



Data source: Annual Progress Report 2013-2014(Anonymous,2015)

Figure 3. Area, production and productivity of Maize in different districts of Sikkim

Specialty in the region

The Indian region rich diversity of maize is mainly concentrated in the North-eastern Himalaya, which supports Asiatic origin of maize; Sikkim Himalaya to be the secondary centre of origin and have landraces known as Sikkim Primitives with primitive characteristics (Karuppaiyanand Avasthe, 2006). The region has unique collection of different landraces. The landraces are named according to the colour of the ear *i.e.* Murali Makkai, Seti Makkai, Pahlenlo Makkai, Rato Makkai, Beiguney Makkai, Lachung Makkai, Sherung, Tempo Rinzing, Garbarey, Khukurey, Kalo Makkai, Putali Makkai, Chaptey makkai, Kuchungtakmar Makkai, Bancharey Makkai, Kuchungdari and Gadbade Makkai (Kapoor *et al.*, 2014). The region also has specific advantages which can be harnessed to good effect in particular with wide diversity. The Indian Council of Agricultural Research- National Organic Farming Research Institute (ICAR-NOFRI) stationed at Tadong, Sikkim has a collection of 26 maize local cultivars which are under evaluation for morphological, phenological and molecular characterization (Sharma *et al.*, 2016). Analysis made clearly demonstrated high genetic diversity in NEH landraces as compared to other regions as well as the genetic distinctness of the 'Sikkim Primitives' (Prasanna *et al.*, 2009).

Gap analysis/ Constraints/Needs in the maize production

- Hill agriculture ecosystems have some constraints of remoteness and problems in terms of moisture stress, poor soil condition and small land holdings *etc.*
- Farmers in the region generally adopt maize-fallow cropping system which results in the lower cropping intensity. Therefore, there is need to enhance the productivity crop in Sikkim to meet the rising demand for the food and feed grains. The maize-based cropping systems with incorporation of intercroops or sequential crops should be practiced in the hilly ecosystems of the Sikkim.
- The soils of the Sikkim are mainly acidic in nature. Therefore, suitable cultivars/varieties should be identified which acclimatize with the soil properties such acid tolerant varieties.
- Maize is nutrient exhaustive crop which consumes the soil nutrients more aggressively, therefore, there is need of maintaining the soil fertility.
- Seed is the main basic inputs of the crop production. Improved, HYVs seeds may not reach the farmers on time, especially in the remote and less accessible areas of the hilly regions.
- Pest and diseases are the other major hurdle in the crop stands. Non-availability of effective organic pesticides and biocontrol agents is also major constraint in the region.
- Low cost farm machinery for tillage practices, interculture operations, harvesting and processing, exclusively suitable for hilly landscapes are not available.

- In spite of consistent functioning of various extension organizations, majority of the farmers of the region is far away from knowledge and adoption of improved organic practices. The farmers are cultivating maize traditionally with their own way.
- Regulated market, processing and storage facilities which ensure farmers for the economic benefit are lacking in the region.

Maize in the cropping system

Under changing agroclimatic scenario maize being a photo-insensitive crop, is a better option for adaption and mitigation. Therefore, it has immense potential as part of crop diversification. *i.e.*, maize-based high value cropping system. Growing legumes crops in a cropping system is well-known practice for restoring soil fertility. Also, maize has compatibility with several crops of different growth habit that result into development of different intercropping systems. At lower hills and mid hills, ginger has also been cultivated as an intercrop and this is an important system for Sikkim. Peas and potato are the intercrops in the high hills. Turmeric and lady's finger are also grown in the lower and mid hills. In high hills, maize + soybean is very good intercropping practice for the region. Following maize based cropping systems are recommended for Sikkim (Singh *et al.*, 2012, Singh *et al.*, 2018).

Existing Cropping Systems

- Maize-fallow
- Maize-rice
- Maize-buckwheat

Diversified/Intensified cropping systems (under irrigated condition)

- Maize+beans-vegetable pea
- Maize-*Pahenlo dal*-cole crops
- Maize-*Pahenlo dal*-coriander
- Maize (green cobs)-*Pahenlo dal*-fenugreek (leafy vegetable)
- Maize-French bean-vegetables (cauliflower/broccoli/cabbage/Spinach)
- Maize (green cobs)-*Pahenlo dal*/*Kalo dal*-vegetable pea
- Maize (green cobs)-rice-vegetable pea/coriander/fenugreek (leaves)
- Maize-*Pahenlo dal*-leafy mustard

Diversified/Intensified cropping systems (in rainfed condition)

- Maize (green cobs)-*Pahenlo dal*-buckwheat/toria
- Maize+beans-vegetable pea
- Maize+beans-rajmash
- Maize+beans-buckwheat

- Maize-black gram/green gram/French bean

Strategies for maize productivity improvement in Sikkim

The overall decline in the maize yield under future climate scenarios can be alleviated by early planting, organic nutrient management and shifting to high yielding, acid tolerant and heat resistant varieties (Deb *et al.*, 2015). New production technologies offer great promise for increasing productivity to meet the growing demands of food grains of the region. Therefore, there is need to intensify and diversify existing maize-fallow system by inclusion of more number of crops per unit area. Selection of crops which fit well in the cropping system is a vital task.

Introduction and promotion new improved maize varieties which are consistent in economic production as well as suitable for changing weather condition have proved to be an important agro-adaptation measure to mitigate climate change (Tachie-Obenget *et al.*, 2013). In Sikkim, farmers generally grow local cv. of maize, which take around 140-155 days from seed to seed. While composite varieties (Vivek Sankul-31, Vivek Sankul-35, RCM 1-1, RCM 1-3, RCM-75 and RCM-76) tested at ICAR-NOFRI Sikkim mature in around 110-115 days from seed to seed (Avasthe *et al.*, 2017). It saves around 30-40 days over local maize cv. grown by farmers in Sikkim. Babu *et al.* (2017) recommend the variety Vivek QPM-9 for cultivation in mid hills of Sikkim which fits well in the maize-based cropping system. Singh (1996) reported that maize genotype 'RCM 1-1' was the most suitable genotype with good stability for days to tasselling, days to silking, days to maturity, cob length and grain yield suggesting that this genotype can be cultivated under mid altitude conditions of Sikkim. Singh *et al.* (2012) mentioned suitable varieties especially for Sikkim condition were as: a) *Composite*: RCM-1-1, RCM 1-76, RCM 1-3, Vivek Sankul Makka-11, Vijay, Prabhat, Gujarat Makai-6 b) *Hybrids*: Vivek Hybrid-9, Vivek Hybrid-21, Vivek Hybrid-33, Vivek Hybrid-39 c) *QPM*: Vivek QPM-9, HQPM-1.

Socio-economic survey revealed that maize and ginger intercropping proved profitable because of difference in their crop growth and nutritional requirements (Tripathi *et al.*, 2003). After harvest of maize crop, pulses (rajmash, black gram, green gram *etc.*) can be grown as succeeding crop during pre-*Rabi* season without any moisture stress to the crop to increase the cropping intensity (Das *et al.*, 2016). Pulses improve soil fertility through biological nitrogen fixation with the help of *Rhizobium* bacteria which benefit component and subsequent crops. Prasad *et al.* (2016) revealed that minimum tillage with crop residue mulch improved the yield of component crops by 5-22% as well as increased the maize-based cropping system productivity. The soil acidity can be managed with the use of liming material. Organic manures, vermicompost, biofertilizers, green manuring crops play important role in nutrient supplementation to the maize crop as well as maintenance of soil fertility (Singh *et al.*, 2012).

The intensified cropping systems *viz.* maize-rajmash, maize-toria, maize-buckwheat, maize (green cobs)-urbean-buckwheat were significantly superior over maize-fallow system under rainfed conditions of Sikkim at mid-altitudes in terms of productivity, production efficiency, profitability, land use efficiency, employment generation and energy-use efficiency (Babu et al. 2016). Babu et al. (2016) recommended that growers can select maize (green cobs)-urbean-buckwheat cropping system under rainfed conditions for sustaining their livelihood security especially in the mid hills of Sikkim Himalayas. Additionally, plenty of biomass available in the region could be used as mulch material for in-situ moisture conservation and make it possible for the *Rabi* crops. ICAR-NOFRI, Tadong (formerly ICAR Sikkim) has developed maize+beans-vegetable pea cropping system to overcome these problems in the rainfed areas (Singh et al., 2017).

Maize Improvement for Sikkim-Breeding Strategies

Maize is one of the most important crop of Sikkim with large wealth of genetic diversity. The region has been mentioned as secondary centre of diversity of maize where it is cultivated at an altitude ranging from 300-1800 m amsl. The local maize cultivars of Sikkim are popular globally and have been specially mentioned owing to their peculiar characters. Around 16 local maize cultivars are available in Sikkim *viz.* Pahelo Makkai, Seti Makkai, Rato Makkai, Baiguney Makkai, Chaptey Makkai, Putli Makkai, Kalo Makkai, Gadbadey Makkai, Kuchungdari Makkai, Murali Makkai, three forms of Sikkim primitives namely yellow, white and dark orange. Maize improvement strategies for Sikkim are:

- i. Sikkim is rich in maize diversity which has variable range of characters. The germplasm has to be evaluated for desirable traits like prolificacy (> 2 cobs/plant), disease resistance, cobs with fully covered husk, cob length, lodging resistance, high yield under low input and earliness (early maturity duration).
- ii. Utilization of Sikkim Primitives *i.e.*, Murali Makkai in breeding programs for transfer of prolificacy into elite cultivars for development of baby corn/ pop corn varieties and also improvement of Sikkim primitives for yield and other related traits.
- iii. As local maize landraces have better adaptability, population improvement programs utilizing local landraces in recurrent selection program will generate better populations. Focus should be emphasized on development of high yielding composites with inherent disease and pest resistance suitable for cultivation under organic conditions.
- iv. Disease resistance is one of the most important aspect in maize improvement. Some of the local cultivars like Kalo Makkai, Baiguney Makkai and Rato Makkai are relatively tolerant to turcicum blight disease. Maize germplasm with turcicum blight resistance are needed to be incorporated in population improvement programs.
- v. Some early maturing cultivars are available in Sikkim which can be utilized as a source for development of early maturing populations/inbreds.

- vi. Two medium maturity composites coded MS8-1 and MS4-1 have been developed at ICAR-NOFRI for maize growing areas of Sikkim having an average yield of 4.0 t/ha under organic conditions. These are in the first year of AICRP- Maize testing.
- vii. Vast diversity of maize in Sikkim can be best utilized by developing inbred lines from the local material for development of composites and hybrids. Research efforts for development of suitable hybrids for Sikkim and other NEH states have to be streamlined for development of inbred lines with good GCA (general combining ability) is needed.
- viii. Protecting and strengthening conservation programs of maize genetic diversity and special efforts on farmers' participation for in-situ preservation of local maize landraces.
- ix. Evaluation and selection of best material from All India Coordinated Maize Improvement trials suitable for the local ecology of Sikkim.
- x. Increase in the number of Multi-Location Trial within the state to have a better picture of the adaptability of the variety to diverse conditions within the state.
- xi. Emphasis on seed production of recommended composites and hybrids (if available) for the state to fulfill recurring demand of high quality seed material of farmers.
- xii. Sensitizing and awareness among the state agricultural officers on new maize technologies and varieties recommended for the state or zone.
- xiii. Training of farmers on organic seed production of both composites and hybrids of maize along with promotion of seed village scheme for fulfilling seed demand.

Scope for value addition of maize

In addition to being staple food maize has range of multiple uses. It serves as basic material for various industrial products like alcoholic beverages, ethanol, plastic, pharmaceuticals and paper industries *etc.* In India, the primary source of starch is maize which is highly demand in the textile industry. Many processed products like food ingredients, boot polishes, cosmetic products derived from maize are part of our daily life. Further, along with Sikkim the whole North East India has wide scope for establishment of value addition chain. It predominantly offers a means to increase and stabilize farm income through assured trading of the row produce at better price. Value addition units /project could create employment generation in area which can lead to rural as well as social development. The use of maize in livestock and poultry feed is getting remarkable importance and there is good scope for developing the feed industry in North East. There is need to identify and analyse strategies for value addition and processing. Commercialization, promotion and adaption of maize based value added food produces will not only ensure higher return to farmers but also generate employment for local people. Other diversified uses could be as popcorn, baby food, corn flacks, corn oil, which offer possibilities for start-ups.

Interventions of maize production technologies

The co-ordination of the outputs of farm research through mass participatory approach is very necessary for adoption of new technologies on the farmers' field. The wider and self-possessed adaptation is the actual initiative of the spread of the newer technology at local level. There is need to reduce the gap between research trials and farmer's field demonstrations.

Various research and extension organizations are being forced and motivated towards the strengthening of the main cropping systems. In Sikkim, ICAR- National Organic Farming Research Institute has taken lead role towards the organic cultivation of maize with standardized package of practices. Additionally, other institutes like ICAR-KVK, KVKs governed by the state government, Agriculture Departments are involved in training programmes for the farmers' awareness.

Over the years, ICAR-NOFRI has experimented and demonstrated various organic crop production technologies through various projects like National Project on Organic Farming (NOPF), National Initiative on Climate Resilient Agriculture (NICRA) and National Mission for Sustaining the Himalayan Ecosystem (NMSHE) in various villages of Sikkim. ICAR Seed Project has been initiated in the 12th Five-Year Plan in the region to meet the requirement of quality seeds of important crops. Under collaborative approach with agencies like NABARD, State Agriculture Department and ICAR-NOFRI *etc.* various demonstrations, capacity building programmes and trainings has been imparted at various villages. The basic farm inputs as seed, organic nutrient supplements *etc.* have been provided to the local communities under input support programme.

During the year 2015-2016, the maize based intensive cropping system *i.e.* maize- black gram (*Pahenlo dal*)- buckwheat was demonstrated by ICAR- NOFRI in the fields of 110 farmers covering an area of 10.4 ha at various locations and recorded high B.C. ratio of 2.59 over the farmers' practice (maize-fallow) with B:C ratio of 1.14 (Avasthe *et al.*, 2017). Various group discussions, farm visits and awareness programmes were conducted with promise of every possible support from ICAR-NORFI to promote the organic maize production in Sikkim region. Furthermore, farmers are also trained for efficient utilization of available resources and crop production in hilly terrain.

Conclusion

Sikkim has great scope and opportunities in maize-based organic production systems. However, there are several threats and weaknesses. Various factors influence the economic returns through organic maize production. Sustainable crop production has positive impact on the socio-economic status of the farmers. There is need to bridge the gaps between the adaptation of techniques of sustainable maize production at farmers' field in terms of production and productivity. The present evidences suggest research and extension efforts are essential for the wider adoption of improved cultivation strategies. Also it is important to examine the status

maize organic farming and feasibility of different farming practices in different production systems and agro-climatic situations in Sikkim.

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SIGNIFICANCE, STATUS AND STRATEGIES OF MAIZE PRODUCTION IN MANIPUR

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Manipur being endowed with salubrious climate, agriculture has been the principal occupation of the state. About 80 % of the state population is engaged in agriculture and allied sectors. The size of the cultivated area is about 10.46 % only to the geographical area of the state. Of this total cultivated area, 52 % is confined to the valley. In the valleys, permanent cultivation is prevalent while the tribal people living in the hills usually practiced shifting cultivation. Maize (*Zea mays* L.) is the second most widely grown crop next to rice in both the hills and foothill valley. It is mainly grown in hilly areas with an altitude ranging from 850-1800 above msl. Being a versatile crop, it has a special significance in the hilly areas of the state. The hill districts share the maximum area (76.58 % of the total area under maize) and also the production (75.82 % of the total maize production). However, the productivity of maize in hill districts (2.22 t/ha) is little lower than the foot hills and upland valley area (2.33 t/ha). Farmers mainly grow local varieties as the state is rich in maize diversity. But under experimental conditions it reached upto 5.00t/ha. However, farmers started preferring composites and hybrid maize varieties since the last couple of years after realizing the superiority from the demonstration programmes. The main causes of low productivity of maize in Manipur are unsuitable methods of planting, low yield of local varieties/seeds, non-availability of quality seed of high yielding/hybrid varieties in sufficient quantity, high seed rate and nutrient deficiency to the crop.

In the North Eastern Hill Region (NEHR), despite of high annual rainfall (>2000 mm) and rich in soil organic carbon content (Choudhury *et al.* 2013), occurrence of frequent dry spells in the coarse textured rain-fed upland soils with high runoff and soil erosions (>80 metric tonnes per hectare) (Patiram 2007) along the sloppy landscapes resulted in poor seed germination or drying up of the emerging seedlings which causes poor crop stand. With the increasing evidence of fluctuation in seasonal rainfall and wide variability in distribution, frequent occurrence of extreme weather events coupled with scanty water resources across the NEHR (Choudhary *et al.* 2013), the rainfed maize productivity with the existing low yielding genotypes in the region is exposed to a high risk of partial to complete failure. Adoption of marginal to almost negligible external inputs in the form of fertilizers and other agrochemicals often compounded the abiotic and biotic stresses in the rainfed uplands with acid soils and causes further reduction in productivity.

Therefore, successful maize production depends on the correct choice of genotypes and application of production inputs to sustain the environment as well as economic production. The

success and level of profit from maize depend on the choice of maize genotypes (hybrids/composites) grown (Ansari *et al.*, 2016; 2017a, 2017b). Timely availability of seeds of location specific suitable genotypes and promotion of can provide a major breakthrough in production and productivity. High yielding varieties (HYV) of maize widely adopted in other parts of country, but in the NEHR, most of the farmers are growing low yielding local varieties, less adaptive to changing climate, particularly rainfall and temperature trend. The information on interaction of phenology of these HYVs and ambient temperature in maize performance under rainfed, acidic soils in the hilly ecosystem of NEHR is very important. It is anticipated that HYVs of maize with better management practices have immense potential to increase the existing production level by 2-3 times in the hilly ecosystem of NEHR.

Significance:

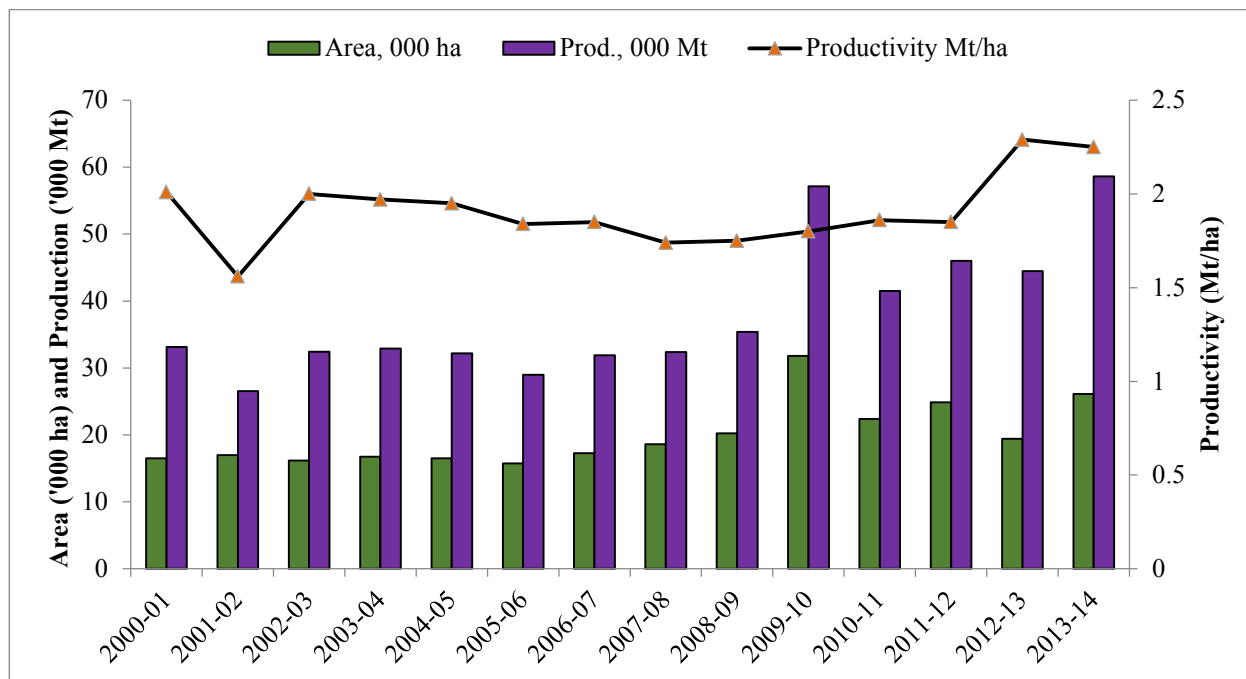
The queen of cereals “maize” occupies a prominent position with higher yield potential among the cereals. It is primarily grown for grain and secondarily for fodder and raw material for industrial processes. It is an important source of carbohydrate, protein, iron, vitamin B and minerals. Every part of the maize plant has economic value: the grain, leaves, stalk, tassel, and cob can all be used to produce a large variety of food and non-food products. Various alcoholic beverages and industrial products are produced by maize distillery and fermentation industries. It has its utility at all stages seedlings till harvest as fodder, flowering as baby corn with fodder, green cobs as sweet corns cobs, grains for various grain purposes including human and animal feed and a source of biofuel too. The fermentation of maize starches and sweeteners has made it an important feedstock for ethanol, which is being used as a bio-fuel. Industrial use of maize is limited at present. However, there exists a scope for using maize as a basic raw material to several industrial products such as alcoholic beverages, food sweeteners, pharmaceutical, cosmetic, textile, package and paper industries.

Status of maize cultivation:

Cultivation of maize plays an important role in subsistence farming which is being practiced by majority of the small and marginal farmers, especially in the hill districts of Manipur. The state is bestowed with suitable agro-climatic conditions for successful cultivation of maize. In the hilly terrains, maize is cultivated in the jhum land or on foothills/terraces. The state is rich in maize diversity and a wide variation of local varieties are available both in hill and valley areas. Farmers usually cultivated local varieties but presently high yielding varieties have gained popularity. Use of local varieties, lack of suitable varieties for jhum cultivation, negligible use of agro-chemicals especially in hills, low moisture retention capacity of upland soil, lack of irrigation facilities, improper weed management, insect pest and disease infestation along with traditional management practices have resulted into low productivity of maize in the state. In recent years rabi maize has been introduced and yielded reasonably high in the valley where

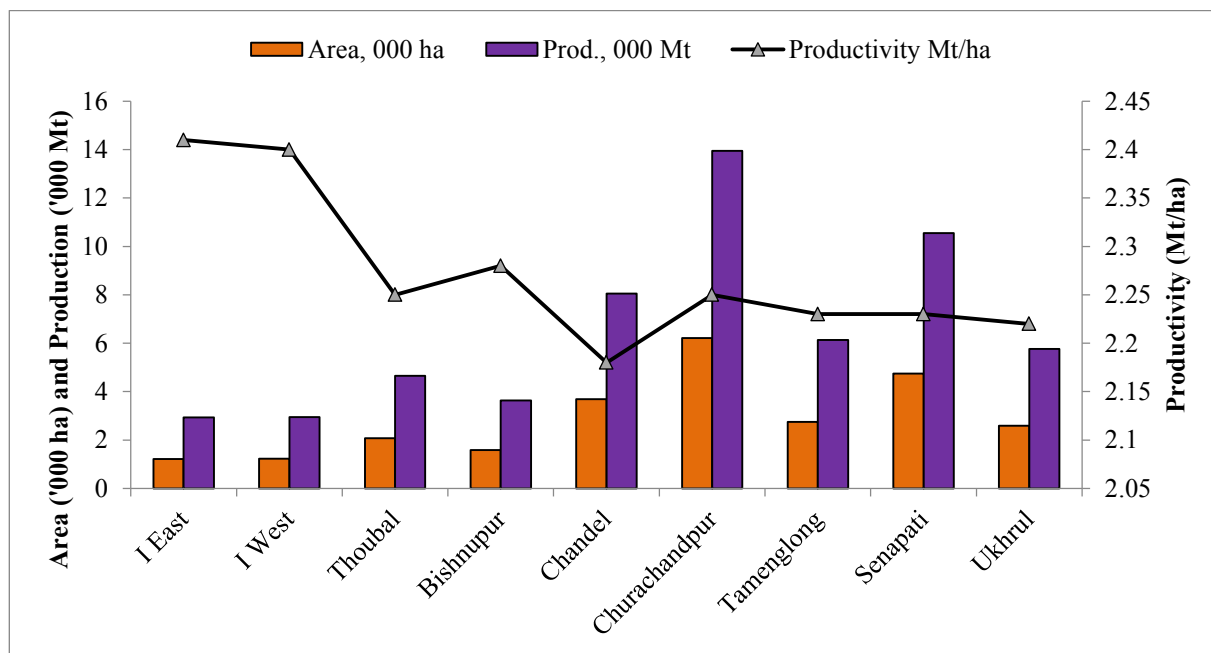
water resources are available, like Kakching area as an intercrop with other rabi crops (Singh, et al, 2008).

The area, yield and production under maize crop are depicted in figure as below.



Estimated area, production and productivity of maize trend in Manipur

(Source: Department of Agriculture (DoA), Government of Manipur 2013-14)



District wise area, production and productivity of Manipur, 2013-14

(Source: Department of Agriculture (DoA), Government of Manipur 2013-14)

Constraints:

There is a compelling need to increase maize productivity vertically in Manipur due to less availability of land and greater dependency of the population on the productivity of the land. Manipur is a landlocked state as there is poor road connectivity with other states. This leads to inaccessibility of procuring quality seed material from outside. Based on the availability of seed in the market, the farmers are compelled to choose among the varieties available in the market.

Being a hilly region, farm mechanization is non-existent and the non-availability of pesticides and bio-control agents are the major constraints of this region. Moreover, the farmers have a mindset against the use of plant protection chemicals. The need for the use of pesticides is important because the region is very humid and the incidence of pests and diseases on maize is high. Further, agriculture in Manipur is rainfed and there is no tube well or well irrigation practiced by the farmers. The dams present are not able to cater the needs of the fields in lean season. The improved agricultural technology knowledge have not been transferred and adopted widely by the farmers. The farmers are still cultivating the traditional varieties of maize in their own way. Availability of quality seeds has been hampering. The ICAR RC NEHR, Manipur Centre has initiated pilot demonstrations on F1 Seed production since last few years with MoU with VPVKAS Almora (UT). Locally developed Composite varieties (unreleased) RCM -76 are proposed for release as composites are easy for the seed chain in the remote hills. The institute so far could not release any variety. The farmers in hilly region widely practices shifting cultivation and are the most highly unscientific use of land resulting into low productivity of the crops.

Scope of maize production:

- ✓ Single cross Hybrids of maize are widely adopted in other parts of country since last decade, which significantly jumped the productivity and production but in the NEHR, most of the farmers are growing low yielding local varieties and deteriorated composite populations due to repeated use for several years which are less adaptive to the changing climate.
- ✓ Because of its deeper root system over rice, maize has been a well adapted crop in the uplands of the North east hill states. It is a major component in the traditional mixed crop under Jhum lands. Introduction of Single cross hybrids would ultimately enhance the yield and productivity.
- ✓ Under the Diversified the paddy based mixed (0.5 to 1.0 t/ha) farming from Jhum areas with High Yielding Single cross hybrids are the preferred seeds of maize for achieving high yield. Hybrid seed technologies in maize can immediately double the yields.
- ✓ In the valley, rabi/summer sowing can be an additional combination with the rabi crops like rapeseed mustard and peas, potatoes. It fill-up the fields before kharif rice after the harvest of rabi crops. It plays an important role in Sustainable maize based cropping system (horizontal or vertical) and may promote with inclusion of pulses in Hill areas, where productivity is very less e.g., Jhum farming.

- ✓ Historically maize was used more for local consumption in various forms and less for commercial use in Manipur. Maize utilized for direct human consumption has reduced over the years and is expected to further reduce due to rising income levels which changed the preferred cereals like wheat and rice more affordable. There is increase in commercial demand from poultry and livestock sector leading to higher farmer realization.
- ✓ Introduction of quality protein maize, QPM produces 70-100% more of lysine and tryptophan than the most modern varieties of tropical maize. Therefore, the QPM can be utilized for diversified purposes in food and nutritional security as infant food, health food/ mixes, convenience foods, specialty foods and emergency ration, in fulfilling the protein requirements of different sections of society (infants, lactating mothers' convalescing patients, Kwashiorkor diseased, old persons and infirm, etc.) to prevent malnutrition.
- ✓ Quality Protein Maize (QPM) with its high carbohydrates, fats, better quality proteins, some of vitamins and minerals, is nutritious feed for poultry, livestock, swine, fish, etc. Use of QPM as poultry feed leads to early development of broilers, save energy and feed, and also the extra cost incurred on lysine and tryptophan fortification.
- ✓ The nutritious products developed from QPM can replace fancied and highly priced industrial foods. These products can also be prepared in villages and thus could be a great source of rural entrepreneurship. Therefore, QPM based rural industries has a wider scope for employment generation and rural prosperity.
- ✓ As per demand of the people of the region as well as market as organic products, particular crops should be selected, where Baby corn and sweet corn may also included in demanding crops for organic production in the region.
- ✓ Sweet corn is genotypes with specific endosperm mutation like *su* and *sh*. In India, sweet corn green ears of field corn are consumed. Standard sweet corn at the immature, milky stage contains about 10 percent sucrose, while field corn in the same stage has about 4 percent sucrose. After harvest or if left on the stalk too long, sucrose in standard sweet corn is rapidly converted to starch. Freshness increases the pricing. To compete and find a nearby niche (like restaurant or roadside stand) for sweet corn, entrepreneurs should explore the potentials of moving these corns to consumers within a day of harvest.
- ✓ Baby corn is the ear of maize plant harvested young, especially before or just after the silk emergence. Currently maize cultivars originally developed for grain usage are grown for baby corn purpose. The dehusked ears are crisp, sweet, succulent, delicious and can be eaten as salad vegetable. There is also an opportunity for entrepreneurship development through baby corn, sweet corn based products.

Strategies for maize productivity improvement:

- 1) Adoption of better cropping pattern: In Manipur, less geographical area is utilized for cultivation of agricultural crops; however, there is a little scope to increase the area under cultivation in the valley. About 98% cultivated area is rainfed. Maize which has the higher

degree of tolerance to water stress over rice fit better in the upland conditions during kharif. This indicates that there is scope for diversification of food crops based on cropping systems approach under specific management.

- 2) Diversification of low yielding rice based mixed farming through sustainable maize based cropping system with inclusion of pulses. Maize has wide adaptability and compatibility under diverse soil and climatic conditions. It is an ideal crop for intercropping and therefore, it is considered as one of the potential drivers of crop diversification. Intercropping of maize with legumes not only improved the productivity and profitability but the incorporation of legume residues help in gaining the nitrogen content of soil thereby saving it for the succeeding crop.
- 3) Selection of drought avoidance varieties with high water use efficiency under rainfed conditions.
- 4) Nutrient management: Maize is an exhaustive crop and requires balanced supply of all the major nutrients as well as zinc. The hybrids of maize are very responsive to external supply of nutrients. Besides chemical fertilizers, the crop is very responsive to organic manures. For achieving higher yields, the nutrient application should be scheduled in such a way so as to match the nutrient-supplying capacity of the soil and the plant demand keeping in view the preceding crop grown in the cropping system. Integrated nutrient management is an important strategy in maize production systems.
- 5) Soil management: Soil acidity is a major contributing factor that affects crop productivity in Manipur. Soil acidity can be ameliorated with minimally processed rock phosphate, basic slag and paper mill sludge. The use of rock phosphate and basic slag containing considerable amount of P would especially be promising, since low P availability is a primary constraint in acidic soils. The ignorance and lack of awareness for soil resources by the farmers make them use abusively without considering the long-term consequences of the practices. Cultivation of crop species, varieties in cropping system to make optimal use of soil resources for food production while conserving soil fertility may be considered as an another measure for managing the soil.

Maize for feed and fodder

In the past the concentrates were comprised primarily of maize grain but now are a mixture of maize and byproducts. The forage part of the corn plant is utilized in three ways. Some is harvested as whole plant maize silage. The silage is used as both an energy source and a roughage source in feedlot diets. Maize silage is also used to “background” cattle. This term is used to describe a growing phase based on forages prior to cattle being placed on “finishing” diets. The second use of maize forage (referred to as residue) is residue harvest after grain harvest and fed as a roughage source in finishing diets or mixed with wet byproducts and fed as an energy source to “background” cattle. The other use of the maize “residue” is through grazing after grain harvest. Calves are placed on the maize fields after grain harvest where they select the

higher quality forage components and any residual grain left in the field after harvest. Residual grain in residue is of high quality and selected first by the cattle. The husk is palatable and highly digested while the leaf is palatable but not as digestible. Quality of the diet declines with time of grazing because the higher quality parts are selected first.

The relative proportions of the various carbohydrates are 77% starch, 2% sugar, 5% pentosans and 1.2% crude fiber. The carbohydrate which forms more than 70% of the maize grain is concentrated in two starchy fractions, floury and flinty, of the endosperm. The sugar in the grain is found in the germ and dietary fiber is in the bran. The endosperm consists of starch granules embedded in a protein matrix. Flinty endosperm has a more rigid protein structure and is also higher in protein content than floury endosperm. The starch in the flinty endosperm consists of 100% amylopectin (large branched molecules), whereas that in the floury endosperm comprises about 27% amylose (linear molecules) and 73% amylopectin. This variation in starch structure does not have any effect on the nutritional value of maize for poultry. The distribution of flinty or floury endosperms in the maize grain determines whether a maize variety is classified as flint or floury (dent) maize. The starch which is the main source of energy in corn has a digestible energy content ranging from 3.75 to 4.17 kcal/g dry matter, thereby making maize one of the highest in energy sources among the cereal grains.

Value addition:

Maize has a great prospective for value addition. The value-added products of maize prepared from normal maize and Baby corn are-

1. Traditional products- laddoo, halwa, kheer, suchi, chapatti, sev, mathri, pakoda and cheela
2. Boiled packed Sweet corn cobs
3. Sweet corn soup powders which may also blended with other ingredients.
4. Popped products- popcorn and popped laddoo
5. Baked products- bread, non-khatai and cake
6. Extruded products-vermicelli and pasta
7. Convenience foods- instant idli mix, instant dhokla mix, porridge mix and sprouted chat.

Likewise, a broad range of products prepared from baby maize are:

1. Traditional products- pakoda, cutlet, chaat, salad, dry vegetable, kofta, mixed vegetable, pickles and raita
2. Sweet products- halwa, kheer and burfi
3. Preserved products- jam, chutney, pickle, candy and murabba
4. Chinese products- soup Manchurian, baby corn chili, chowmein, sweet and sour vegetables.

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RAINFED MAIZE CULTIVATION: PRODUCTION POTENTIAL AND CONSTRAINTS IN MIZORAM

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Maize (*Zea mays* L.) is one of the most versatile photo-insensitive, cold-intolerant C₄ cereals; having wider adaptability to grow under diverse agro-climatic regions of India. India ranks higher among the top ten maize producing countries in the world, contributing around 2-3% of the total maize produced globally that also contributes almost 14% of the total exported maize for other countries around the world. The warm humid tropical to subtropical weather conditions of North Eastern states (including Mizoram) are most congenial for maize cultivation that is also the major source of energy and nutrition for the larger part of indigenous tribal communities against their almost equivalent priority after rice.

In Mizoram, rainfed maize is widely cultivated in the steep slopes of shifting cultivation lands popularly known as 'Jhum'. Such traditional cultivation practices are mostly adopted by the majority of the farmers at subsistent level. Local maize landraces having variable crop vigor, phenology; having multicolored and variable textured gains still dominate in the majority of



Fig 1: (a) Upland rice- local maize (b) pumpkin - local maize integration in traditional jhum farming systems at Bilkwathlir (Kolasib district, Mizoram).

available maize cultivars in jhum lands. Due to greater adaptability of maize towards variable climatic conditions, compatibility to grow under diverse environmental conditions and local traditional food preference, local maize landraces are often integrated with several other accompanying crops viz. upland rice, ginger, pumpkin and vegetables (chilli, brinjal, cucumber, gourds etc.), as mixed crop in the jhum farming systems of Mizoram (Fig 1a & b). The practice is much useful for fetching higher farm income from diversified income generation sources and also reducing the risk of complete crop failure from mono-cropping; has often occurred from

periodic occurrence of natural weather aberrations during the active crop growth period in the major rainfall receiving months (April – October). Moreover, maize has currently limited and scattered area coverage for rabi cultivation in the low-lying areas of Mizoram, mostly due to lack of suitable irrigation water supply infrastructure facilities. In this section, we will confine our present discussion on different aspects of rainfed maize production in Mizoram.

Significance

Food: The taste of local maize landraces got higher preference over the introduced improved varieties (RCM 75 and RCM 76; Fig 2a). The local tribal population usually consume the maize cobs in either boiled or roasted form. The market demand for sweet and pop-corn varieties are mostly concentrated in Aizawl and Lunglei town areas. Almost 90 percent of total maize cultivation is used as food in Mizoram; mostly cultivated in the shifting cultivation lands at subsistence level for their home consumption and periodic market availability as jhum produce (during July-August).



Fig 2(a): Quality Seed Production of RCM-76 at ICAR Kolasib research farm.(time isolation)

Fig 2(b): Jhum Improvement with High Quality Protein Maize (HQPM) at Theiva village (Saiha, Mizoram)

Forage and Feed: Quality Protein Maize (QPMs) is popular as livestock feed material viz. poultry and piggery both mostly in the form of seeds (Fig 2b). Lower cattle population signifies the limited potential of maize cultivation as green fodder in Mizoram.

Other Uses:

1. After deshelling, the residual husk and maize stocks are often used in mushroom culture.
2. The plant residues are often used as mulching material to restrict soil erosion, conserve soil moisture during crop growth period and soil carbon management.

Status of maize cultivation in Mizoram

Maize is one of the principle cereal crop, growing in the jhum lands of Mizoram. At present, the state is far beyond to attain the self-sufficiency in food production for fulfilling the state domestic requirement. Maize cultivation is an indispensable part of existing food production system in Mizoram. However, the average productivity of maize varies between 1.3-1.6 MT / ha against the national values 2.5-3.0 MT/ ha. The detailed district wise rainfed maize production status are displayed in table 1. Serchhip district has highest acreage for rainfed maize cultivation but with least productivity followed by Kolasib and Mamit district. Least productive local maize landraces are usually preferred by the tribal farmers, due to their taste preference that often fetches higher farm income from high market demand.

Table 1: District wise area and production status of kharif maize in Mizoram (2016-17)

Districts	Area (ha)	Production (MT)	Productivity (MT/ ha)
Aizawl	495	831	1.68
Lunglei	477	760	1.59
Saiha	201	382	1.90
Champhai	448	635	1.42
Kolasib	755	973	1.29
Serchhip	1600	2000	1.25
Lawngthlai	565	1622	2.87
Mamit	940	1240	1.32
Mizoram State	5481	8443	1.54

(Note: Area in ha and Production in Metric tonnes)

Biodiversity status: Vast diversity in local maize landraces exists in Mizoram and these collections are classified into three categories based on uses and taste, like *Puakzo* (small cob, popcorn), *Mimban* (small cob, sweet and starchy) and *Mimpui* (big cob, Roasted and feed). Sixty seven landraces of maize were collected from jhum lands in different parts of Mizoram and evaluated for response to variable temperature regime and assessment of agro-morphological characteristics. 34 landraces have been deposited in NBPGR, New Delhi and IC nos. has been obtained. A higher degree of growth variability was observed among these collected landraces



Fig 3: Local collection of maize landraces in Mizoram

Constraints:

- **Lower productivity for the lands under shifting cultivation:** Traditional preference of tribal farmers for practicing shifting cultivation at subsistence level with mixed farming systems. The practices are often resulting extensive C emission during burning, natural habitat destruction, accelerating soil erosion from post burn fallows and mixed cropping with erosion prone crops (maize/other root crops) in the jhum lands. As shifting cultivation is an indispensable part of Mizo culture, it is difficult to eradicate jhum practices (dominated by local maize landraces) completely; even though implementation of different subsidized schemes for promotion of commercial maize production on the Government side.
- **Limited farm input availability:** Inadequate, less efficient agricultural input delivery systems (preferably quality seed materials, newly released formulation of plant protection chemicals) and supply chain deformities. Quality maize seed material is difficultly available to farmers of Mizoram. The Mizoram mostly relies on the traditional low yielder maize land races only.
- **Limited resource inventory:** No systemic cadastral surveys on soil/ecological resources were performed with limited land records exist from the faulty land tenure system. Even, ICAR – NBSSLUP has made the resource inventory for Mizoram at early 1990s. The dataset should be updated immediately covering all the newly formed district boundaries of Mizoram. Remote sensing images are often used to acknowledge the issue but with very limited ground validation process, preferably due to difficult inaccessible terrain condition in Mizoram.
- Rainfed maize cultivation without adaptation of field scale suitable soil water conservation measures (strip cropping/ contour cropping etc) increases extensive soil erosion risk from steep slopes.
- Poor soil health, soil acidity (mostly induces limited anionic nutrient availability) and use of no chemical fertilizer supplementation in jhum fields often induces deformation symptoms in different plant parts that ultimately reduces the average rainfed maize productivity (Fig 4a-h).



(a) Bouquet ears symptom

(b) Tassel ear symptom

(c) B deficiency (tassel)

(d) B deficiency (leaf)



(e) Fe deficiency (leaf)

(f) N deficiency (leaf)

(g) Mo deficiency (tassel)

(h) P deficiency (leaf)

Fig 4a-h: Deformities and nutritional deficiency symptoms often observed in the maize plants grown at farmers' fields in Mizoram

- Profuse weed infestation, high pest incidence (Fig 5a-e) due to high rainfall followed by excess relative humidity percentage and warm weather conditions during kharif season. The details of documented pest incidence in the jhum fields of Mizoram are listed below:

(a) Stem borer: *Chilo partellus*, Crambidae: Lepidoptera

Symptoms of damage: It infests the crop a month after sowing and up to emergence of cobs. Central shoot withering and leading to “dead heart” is the typical damage symptom. Bore holes visible on the stem near the nodes. Young larva crawls and feeds on tender folded leaves causing typical “shot hole” symptom. Affected parts of stem may show internally tunnelling caterpillars.



Fig 5a: Dead heart symptom

ETL: 10% dead hearts.

Management

- Sow the lab or cowpea as an intercrop to minimize the stem borer damage (Maize: Lablab 4:1).
- Set up light trap till midnight to attract and kill the stem borer moths.
- Mix any one of the following insecticides with sand to make up the total quantity of 50 kg and apply in the leaf whorls. Phorate 10G 8 kg, carbofuran 3G 17 kg, carbaryl + lindane 4G 20 kg, endosulfan 4D 10 kg (or) endosulfan 35 EC 750 ml (or) carbaryl 50 WP 1 kg (500 lit. spray fluid/ha).
- Collect the stubbles after harvest and burn to destroy diapausing borers.

(b) Maize aphid: *Rhopalosiphum maidis*, *Longinuis sacchari*

Aphididae: Hemiptera

Symptoms of damage: Maize plant at the end of mid rib whorl stage are usually attached. Aphids suck the sap from plant and cause yellowing and mottling. Diseased plants may become stunted and turn reddish as they are mature. If young plants are infected they seldom produce ears. The aphid colony may sometimes completely cover emerging tassels and surrounding leaves preventing the emergence. Ear and shoots are also



Fig 5b: Aphids on leaves

infested and seed set may be affected. Honey dew excreted by aphids favours the development of sooty molds.

Management

- Release Predators - *Coccinella septempunctata* *Menochilus sexmaculatus*, and *Geocoris tricolor*
- Spray with 0.04% diazine (or) dimethoate (or) 0.02%, phosphomidon @ 250 ml in 450-500 litres water/ha.

(c) Cob borer: *Helicoverpa armigera* (Hubner), Noctuidae : Lepidoptera

Symptoms of damage: It is a polyphagous species and is an important pest on maize in North Eastern region. Caterpillar first feeds on silk and feeds on seeds. Larva is seen feeding with the head alone thrust inside the parts and the rest of the body hanging out. Boreholes on cobs, absence of seeds on cobs and defoliation in early stages are the symptoms of attack.



Fig 5c: Cob borer infestation in maize

Management:

- Install bird perches @ 50/ha to pick up the larvae by birds
- Set up light trap to monitor, attract and kill the moths
- Set up pheromone traps @12 Nos./ha
- Inundative release of egg parasite *Trichogramma* spp. and egg larval parasites,
- *Chelonus blackburnii*
- Spray NSKE 5% twice followed by triazophos 0.05%.
- Apply any one of insecticides at 25 kg/ha. Endosulfan 4D, quinalphos 4D, carbaryl 5D
- Spray endosulfan 35 EC 1.25 lit. (or) monocrotophos 36 SL 625 ml/ha.

(d) Banded leaf and sheath blight

Causal Organism: *Rhizoctonia solani*

Symptoms of damage: Large, discolored areas alternating with irregular dark bands are typical symptoms of the disease. Severe infection leads to blotching of the leaf sheath as well as leave. The symptoms under favorable conditions extend upto silk, glumes and kernels. Disease generally appears at pre-flowering stage. Symptoms also appear on stalk and internodes break at the point of infection. The fungus survives on weed and in the plant debris.



Fig 5d: Banded leaf and Sheath blight symptoms on plant

Management

- Clean cultivation, destruction of crop debris.
- Spray with carbendazim or propiconazole 1 gm/ltr are recommended.

(e) Maize rust

Causal Organism: *Puccinia sorghi*

Symptoms of damage: The fungus affects the crop at all stages of growth. The first symptoms are small flecks on the lower leaves (purple, tan or red depending upon the cultivar). Pustules (uredosori) appear on both surfaces of leaf as purplish spots which rupture to release reddish powdery masses of uredospores. The pustules are elliptical and lie between and parallel with the leaf veins. In highly susceptible cultivars, the pustules occur so densely that almost the entire leaf is destroyed. Teliopores develop later sometimes in the old uredosori or in teliosori, which are darker and longer than the uredosori. The pustules may also occur on the leaf sheaths and on the stalks of inflorescence.



Fig 5e: Reddish, brown exposed uredopustules on leaf

Management:

- Remove the alternate host *Oxalis comiculata*.
- Spray the crop with Mancozeb at 1.25 kg/ha.

Scope of maize production in Mizoram

Maize is suitable for round the year cultivation in all the districts of Mizoram. For rabi maize cultivation, ensured irrigation water supply during non-rainy months is essential. The season of maize cultivation are likewise:

Season	Time of Sowing	Time of harvest
Summer/ pre-kharif (Shifting cultivation)	Second week of April to first week of May	Third week of July to last week of August
Kharif	Mid-August	late November to early December
Rabi (irrigated)	Second week of October to first week of November	Late February to 2 nd week of March

There is a huge year around market demand for maize as food and feed in Mizoram. But the supply chain for the same is yet to be developed, with ensuring the regular technological support to the farming community towards fulfilling the present market demand. Ensured supply of quality input material and providing suitable infrastructure (irrigation water supply, market outlet etc.) to the farmers has the potential to increase average maize productivity in Mizoram. Moreover, this will the farming resiliency against the environmental stress factors and ensure sustainable farm income to the tribal Mizo farmers. Organizing supportive skill development programme on regular basis, for disseminating the standardized maize production technologies emphasizing on soil health management, integrated pest and nutrient management will be useful for better entrepreneurship development for maize production sector in Mizoram.

Strategies for maize productivity improvement in Mizoram

(a) Quality Seed production: Seed materials of high yielding varieties (RCM 75/ & 76/ DA 61) are multiplied and maintained at ICAR research farm (Kolasib) and State Government farm (Thenzawl veterinary farm, Serchhip). Space isolation (isolation distance > 3 m) or time isolation (off season cultivation during rabi season; irrigated condition) is maintained to ensure the regular timely quality seed supply for the farmers in Mizoram. The average yield was recorded by 3.44 t/ha and 3.76 t/ha for RCM -76 and RCM-75 respectively at ICAR Kolasib research farm.



Fig 6a: Maize seed multiplication of RCM 75 at ICAR Kolasib research farm during rabi (november-february; irrigated) season

(b) Crop diversification: Mizo farmers mostly adopt the maize based intercropping systems for getting additional income via. maize+ pigeon pea maize+ soybean, maize+ urdbean, maize+ groundnut, maize+ greengram, maize+ pumpkin, maize+ ash gourd and maize+ cucumber during *kharif* season. Among all pulse and oilseed combinations, soybean + maize intercropping combination is highly preferred by the farmers. Maize yield was drastically reduced with redgram combination. Among the vegetables intercropping options available to grow in the shifting cultivation lands, maize-tomato intercropping fetched highest farm income. However, pumpkin is widely cultivated due to local tribal food preference that increases about 8.12% maize yield; 30.41% reduction in maize yield was observed when intercropped with ash gourd (against sole maize crop).



Fig 7a: Maize+soybean intercropping



Maize-tomato

Maize-pumpkin

Maize-colocasia

Maize-ash gourd

Fig 7b: Vegetable intercropping options with maize in the jhum lands of Mizoram

Soybean (JS-355) as a second crop after jhum maize: ICAR Research Complex for NEH Region, Mizoram Centre introduced soybean cultivation after jhum maize harvest in 5 cluster villages, viz. Theiva, Baulpuii NG, Km Sawm and Niawhtlang-I & II in Saiha district. JS 335 soybean has the potential to grow as a second crop after maize (First week of August planting). The

technology provides a huge scope for residual soil utilization, soil fertility improvement (nitrogen fixing capacity of legumes) and increasing farm income of the tribal farmers. The average seed rate per ha was 70-75 kg/ha and planted on jhum field with spacing of 45 cm x 10 cm. An average yield of 1.48 t/ha was obtained from the harvest crop. Maximum numbers of pods/plant (78.50) was recorded with maximum grain yield of 18.25 q/ha. Therefore, by introducing soybean as 2nd crop could earn an additional net income of Rs. 50,000 per ha with a benefit cost ratio of 2.98:1.



Fig 7c: Increasing farm income and managing soil health through introduction of soybean variety JS-355 as second crop after maize

(c) Soil health management: Maize permits soil erosion from high hill slopes in jhum lands that often depletes soil nutrient status to a greater extent. Majority of farmers in Mizoram, are reluctant to apply external inorganic nutrient supplementation. Therefore, intercropping / strip cropping with legumes (viz. redgram, soybean etc.) was recommended to restrict soil erosion and improve soil fertility status from atmospheric N fixation in the maize growing shifting cultivation areas.

(d) Market chain development

Market chain development is one of the most important component for income generation of the farmers. Previously, Mizo farmers produce maize at subsistent level only for own consumption. After intervention of high yielding RCM varieties, maize yield increased 2.02 times. At present, the high income is ensured to the farmers from the most recent Government initiatives with NABARD for village link road construction and supportive market chain development for different farm produce including maize in Mizoram. Most of the farmers harvested young maize cob and sell it market like Kolasib and Aizawl. However. Matured seeds has a high demand in the established poultry and pig farms at Aizawl.

Value addition and processing potential in Mizoram

- Preparation of traditional tribal food items, healthy foods like snacks, baked products, cookies etc.
- Pig feed block preparation preferably from QPMs
- Bio ethanol and carbonated beverages production
- Establishment of refined corn oil industry etc.

MAIZE PRODUCTION IN NORTH EAST INDIA AND ITS SCOPE IN TRIPURA

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In North-Eastern region (NER) of India, maize is the second most important food grain after rice. The crop has multiple uses as food, feed, fuel, etc. Maize has special significance in the region as ingredient of concentrate feeds for poultry, fish, pig and cattle. Presently, demands for green cob and pop-corn are continuously increasing among the people of the region. Maize is mostly grown under rainfed condition in upland and *jhum* lands, however, it has a great potential during winter (*rabi*) season in rice fallow land where water for irrigation is available. The region receives enough rainfall (>2,000 mm annually), most of which is concentrated in monsoon season but pre monsoon season is also quite wet in this region. After harvesting of the rainy (*kharif*) crops, lack of sufficient soil-moisture availability limits the cultivation of winter (*rabi*) crops in uplands. Blackgram, greengram, rapeseed, French bean, lentil etc. can be cultivated in upland after maize on conserved soil moisture or with life-saving irrigation.

Tripura is both second smallest as well as second most populated state in the North Eastern Hill Region and occupies 1049.69 km² areas. The State is situated between latitudes 22°56' and 24°32' North, and longitudes 90°09' and 92°20' East, and is surrounded by Bangladesh on its south, west and north. The length of its international border with Bangladesh is about 856 km (i.e. about 84 percent of its total border), while it has 53 km border with Assam and 109 km border with Mizoram. Tripura has a tropical climate and receives adequate rainfall during the monsoons. It has diverse range of topography, people, flora and fauna. A large part of the land is up-land / tilla land and hilly, with altitudes varying from 15 to 940 meters above sea level. The prominent hill ranges of the State are Jampui, Sakhantang, Longtharai, Atharamura, Baramura Deotamura, Belkum and Kalajhari. BetlingShib (939 meters) in the Jampui Range is the highest peak of Tripura. In Tripura maize is having potential in 625652 ha tilla (60% TGA) land and 218126 ha (21%) medium upland. However, most of these areas are under forest and only 27% of TGA is under crop production. The state has about 8646 ha area under maize with production and productivity of 11578 t and 1339 kg/ha.

Opportunity maize based cropping system under various resource conservation measures

The rainfall pattern in NER is highly uncertain with poor distributions. May to September receives about 75% of annual rainfall with very little rain in post and pre-rainy season. December to April is mostly dry period. Maize based cropping system has large scope in NER and Tripura under conservation agriculture (CA) to promote sustainability in hill farming. Maize during rainy season followed by pulses and oilseeds during rabi/winter season has great scope under

conservation agriculture. Retention of preceding maize crop residues along with no-till (NT)/Zero till (ZT) is a viable technology for promotion of maize based system in the region. The technology involves cultivation of maize under minimum tillage (MT) using other recommended package of practices. The spacing given to maize is 60 x 20 cm. Maize is sown in last week of April to first week of May and cobs are harvested in first fortnight of August leaving maize stalk standing in field. The standing maize stalk is then detopped leaving about 1 m standing stubble uniformly. The cut portions of stalks are used for mulching the field after germination of succeeding crops. The stalk height is reduced to 0.5 meter if crops other than French bean are to be grown. In between two maize lines, two narrow furrows are opened using a furrow opener or NT seed drill in 30 cm apart. Fertilizer and manure then placed on the furrow and then French bean seed is placed at about 10 cm spacing within a furrow. Cropping systems have been identified as per the location. Maize + soybean –French bean, Maize- rapeseed, maize black gram, maize vegetables (Meghaalaya), maize – black gram, maize + bean,– rajmash and maize + bean – pea (Sikkim), Maize-cowpea, maize-rajmash (Tripura) etc. are some of the prominent cropping systems for the region.

A 4-year field study (2006-10) was conducted at the ICAR Research Complex for the NEH Region, Umiam, Meghalaya, India with zero tillage and residue mulching under maize (*Zea mays* L.)-toria(*Brassica campestris* L.) system. The aims were (i) to evaluate the performance of maize - toria cropping system under zero tillage and mulching with readily available biomass and crop residues and (ii) to select a suitable tillage and residue mulching practice that restore soil organic carbon (SOC) and improve the soil quality. Two tillage practices (conventional tillage- CT and zero tillage- ZT) were compared under six mulching

treatments using on- and off-farm residues viz., control, maize stalk cover (M), M + *Ambrosia* 5 t/ha (MA5), M + *Ambrosia* 10 t/ha (MA10), M + FYM 10 t/ha (MF10) and M + *Ambrosia* 5t/ha + poultry manure 5 t/ha (MA5P5). Grain yields of maize and rapeseed under CT were similar to that under NT. Mulching had a significant effect on the

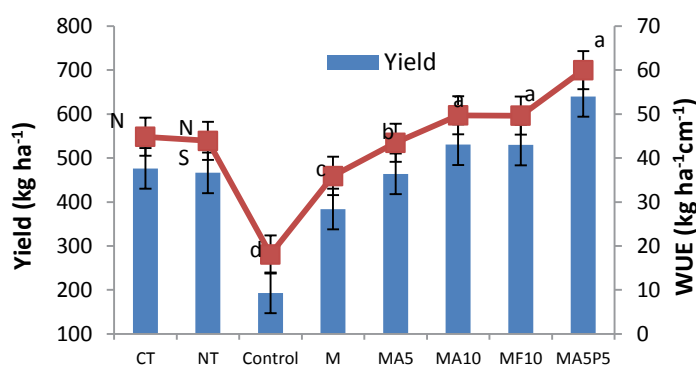


Fig 1. Average rapeseed seed yield and water use efficiency as affected by tillage and residue mulching practices

productivity of maize and rapeseed. Mulching treatment MA5P5, MF10 and MA10 produced significantly ($p=0.05$) higher yield of maize and rapeseed than that of other treatments. Maize and rapeseed productivity under control was the lowest. In general, MA5P5, MF10 and MA10 enhanced maize productivity by 27.5, 23.5 and 21.5 % over that of the control, respectively (Fig 1.). Bulk density and SOC improved under ZT and residues managed plots, compared to the CT. Among the mulch treatments, MSC + *Ambrosia* @ 10 t/ha and MSC +

Ambrosia @ 5t/ha + poultry manure @ 5 t/ha recorded the higher seed yield of *toria*. The yield of both maize and *toria* crops under conventional tillage remained similar to ZT. Available N and P was maximum in MSC + *Ambrosia* 5 t/ha + poultry manure 5 t/ha. The study indicated that effect of soil moisture conservation measures on soil hydro-physical characters, SOC and biological activity was more pronounced under zero tillage than under conventional tillage. Adaption of ZT increased mean SOC by 6%, water stable aggregate by 9.3%, mean weight diameter 42.6%, available soil moisture by 20%, SMBC by 66.8% over conventional tillage system (Table 1). The temperature under conservation tillage was marginally higher. Similarly, moisture conservation measure MSC + *Ambrosia* 5 t/ha + poultry manure 5t/ha enhanced mean SOC by 30.4%, soil available N by 54.8%, mean weight diameter by 100%, hydraulic conductivity by 76% and SMBC by 100 % (Das et al., 2017). Such improvements in soil properties have a direct bearing on long-term sustainability and soil quality in a fragile hilly ecosystem. Therefore, zero tillage and residue management promoted positive changes in SOC, soil physical and microbial properties and improved soil quality.

Table 1. Soil physical quality parameters as affected by tillage and moisture conservation measures

Treatments	BD (Mg/m ³) 0-15 cm	Mean weight diameter (mm)	Water stable aggregates (%)	Hydraulic conductivity (mm/hr)	SMBC (mg/g dry soil)	Dehydrogenase activity (mg/g dry soil)
Tillage						
Conventional tillage (CT)	1.19	1.48	59.8	2.21	88.6	121.1
No-till (NT)	1.08	2.11	65.4	2.76	53.1	99.50
CD (P=0.05)	NS	0.22	4.68	0.55	09	07
Residue mulching						
Control	1.20	1.13	41.5	1.76	43.7	40.6
Maize stalk cover (M)	1.19	1.34	56.9	2.0	57.9	66.8
M + <i>Ambrosia</i> 5t/ha	1.13	1.79	64.7	2.22	69.1	123.4
M+ <i>Ambrosia</i> 10t/ha	1.10	2.16	70.5	2.98	87.1	155.0
M + FYM 10 t/ha	1.11	2.07	68.9	2.85	78.2	124.1
MSC + <i>Ambrosia</i> @ 5t/ha + Poultry manure 5t/ha	1.12	2.27	73.1	3.1	89.3	151.8
CD (P=0.05)	0.23	0.23	3.16	0.44	8.50	6.95

Among the six residue mulching practices, MSC+ *Ambrosia* 5t/ha + poultry manure 5t/ha recorded highest grain yield of maize followed by MSC + FYM 10t/ha and MSC + *Ambrosia* 10t/ha (Table 2).

Table 2. Grain yield (t/ha) of maize as influenced by tillage and residue management.

Treatments	NT	CT	Mean
Control (No mulching)	3.42	3.81	3.62
Maize stalk cover (M)	3.50	3.83	3.67
M + <i>Ambrosia</i> 5 t/ha	3.91	4.20	4.06
M + <i>Ambrosia</i> 10 t/ha	3.72	4.97	4.35
M+ FYM 10 t/ha	3.91	4.11	4.01
M + <i>Ambrosia</i> 5 t/ha+ poultry manure 5 t/ha	4.27	4.93	4.60
Mean	3.79	4.33	4.00

The soil samples from different tillage practices and residue management practices were collected for analysis SOC content from a field experiment under maize- toria system conducted since 2006. The SOC values (Table 3) were maximum NT followed by CT at 0- 15 cm and 15- 30 cm soil depth. Among the residue mulching practices the SOC in MSC + poultry manure 5t/ha + *Ambrosia* 5t/ha was highest in 0-15 cm and 15-30 cm. Application of crop/weed biomass along with 50% resulted in sustainable improvement of organic carbon in the soil. Application of 50% NPK and 100% NPK alone resulted in lower SOC content in the soil.

Table 3. Soil organic carbon content (%) at two soil depth as influenced by tillage and residue mulching practices (after 5 cropping cycle).

Treatments	0-15 cm			15-30 cm		
	NT	CT	Mean	NT	CT	Mean
Control (No mulching)	2.25	2.20	2.23	1.7	1.63	1.67
Maize stalk cover (M)	2.24	2.17	2.21	1.87	1.72	1.80
M + <i>Ambrosia</i> 5 t/ha	2.35	2.27	2.31	2.01	1.95	1.98
M + <i>Ambrosia</i> 10 t/ha	2.26	2.22	2.24	1.9	1.78	1.84
M + FYM 10 t/ha	2.23	2.19	2.21	1.97	1.83	1.90
M + <i>Ambrosia</i> 5 t/ha+ PM 5 t/ha	2.26	2.22	2.24	2.12	2.09	2.11
Mean	2.27	2.21	2.24	1.93	1.83	1.88

The soil moisture status in toria field was higher under zero tillage/NT compared to CT throughout the growing period of toria. The productivity of succeeding toria crop after maize

was about 18.7% higher under NT compared to conventional tillage (Table 4). Among residue mulching practices, MSC + *Ambrosia* 5 t/ha + Poultry Manure 5 t/ha recorded maximum yield, which was about 250% higher than control (No mulching). Thus, results revealed the potential of resource conservation technologies in conserving soil moisture, improving soil organic carbon, saving energy and finally giving sustainable production in hill ecosystem of North East India.

Table 4. Seed yield (t/ha) of toria as influenced by interaction effect of treatments

Treatment	CT	ZT	Mean
Control	0.16	0.22	0.19
Maize stalk cover (M)	0.45	0.47	0.46
M + <i>Ambrosia</i> 5 t/ha	0.50	0.62	0.56
M + <i>Ambrosia</i> 10 t/ha	0.58	0.72	0.65
M+FYM 10 t/ha	0.57	0.68	0.60
M + <i>Ambrosia</i> 5 t/ha + PM 5 t/ha	0.64	0.72	0.68
Mean	0.48	0.57	

Adoption of conservation practices like NT and retention of stalk/residues of preceding maize crop along with mulching with fresh *Ambrosia* sp. biomass (10 t/ha) maintained higher soil moisture status (10-15 % higher than removal) throughout the growing season of succeeding rapeseed/French bean crop. The seed yield of rapeseed recorded with retention of preceding maize stalk along with mulching with *Ambrosia* was 350% higher than that without residue management (Control). The yield of French bean in maize-fallow was also enhanced by almost two times due to adoption of NT and retention of maize stalks. The highest maize equivalent yield (MEY) was obtained from maize-French bean (pole type) system under retention maize stalk mulch (MSM) + *Tephrosia candida* (10 t fresh biomass/ha) mulch (9.5 t/ha) followed by MSM+ *Ambrosia artimisiifolia* (10 t fresh biomass/ha) mulch (8.8 t/ha). In farmer's field also the net return recorded with maize-French bean, maize-toria and maize monocropping was Rs.19620, Rs. 6520 and Rs. 3470, respectively, from 2000 m² area. The maximum water use efficiency (WUE) was recorded with maize-French bean (11.58 kg/ha/mm) sequence was much higher compared to maize monocropping (6.23 kg/ha/mm) (Das et al. 2014).

Maize being an exhaustive crop also depletes soil fertility. The study on judicious integrated nutrient management strategy revealed that application of full dose of inorganic fertilizer along with *Azolla* compost 2.5 tons/ha application to maize not only enhanced productivity of maize-mustard cropping system by 90% and 13.4% over the control and recommended N, P and K, respectively, but also improved soil fertility. Nutrient uptake and soil fertility at final harvest (kg/ha) as influenced by organic and inorganic sources of nutrients. This

nutrient management option had considerable residual effect on succeeding mustard in terms of yield and income (Das *et al.*, 2010).

The region has very large biodiversity of maize germplasm covering diverse color, shape, size etc. There is huge scope for promoting organic maize production in the region. Cultivars like DA61A, RCM 75 have been found suitable for organic production as again hybrids and other varieties due to their tolerance against various pests, acid tolerance and suitability to fit with various pulses and oilseed based cropping systems including vegetables. Maize + soybean - French bean system has been identified as potential cropping system for promotion of organic farming in the region (Das *et al.*, 2014). Integrated application of nutrient through 1/3 FYM +1/3 vermicompost + 1/3 Local compost to provide recommended N has been found suitable for higher maize productivity under Umiam, Meghalaya. Rock-phosphate @ 150 kg/ha during sowing has been recommended to take care of the phosphorus nutrition of maize crop. In the absence of integrated source, application of entire nutrients through FYM has been found equally effective (Das *et al.*, 2014).

Technology for maize production in Tripura

Maize in Tripura is having very good potential especially during pre-kharif and rabi season. Several open pollinated varieties/composites and hybrids have been tested under Tripura conditions over the years. Composites and OPVs like Vijay, DA61A, RCM 75 and RCM 76 performed well under Tripura Conditions with yield ranging from 3 to 4 t/ha. Maize hybrids like Vivek maize hybrid 23, Cmh 08-239, Cmh 08-239 etc. performed well under Tripura conditions with kernel yield of 4.5 to 5.3 t/ha.

Maize in Tripura conditions responded up to 120 kg N, 80 kg P and 60 kg K/ha. Liming is another potential technology for enhancing yield of maize in acid soils of Tripura. Furrow liming @ 500 kg/ha has been recommended for ameliorating soil acidity which has the potential to enhance maize yield by 30% in the NER. Maize-French bean, maize-cowpea, maize- rapeseed- ,mustard, maize- rice (upland), rice-winter maize (lowland) are some of the potential maize based cropping systems for Tripura.

Some experimental results under Tripura conditions are indicated below-

Performance of extra-early, early and medium single cross hybrid maize in Tripura (kharif)

- CMH08-337 hybrid recorded maximum plant height as compared to other hybrid as well as local variety (Table 5)
- Days to 50% pollen shed, days to 50% silking and days to 50% dry husk were less in all the tested hybrids as compared to local check. However, Vivek QPM 9 and Vivek Maize Hybrid 21 required minimum number of days to 50% pollen shed, days to 50% silking and days to 50% dry husk as compared to other hybrids (Table 5).
- CMH08-337 recorded maximum ear height among hybrids as well as local check (Table 5)

- All the hybrids had higher cob weight, cob weight/plot, 1,000 grain weight, grain weight and grain yield/plot as compared to local check. However, CMH08-239 was recorded maximum cob weight, cob weight/plot, 1,000 grain weight, grain weight and grain yield/plot as compared to other hybrids (Table 6).

Table 5. Performance of Extra-early, early and medium single cross hybrid maize in Tripura during kharif 2012

Treatment	plant height (cm)	Days to 50% pollen shed	Days to 50% silking	Days to 50% dry husk	Ear height (cm)
Peehm 5	209.7	43	48	72	25.3
Vivek QPM 9	191.7	38	43	70	23.0
Vivek hybrid 9	197.7	39	43	68	22.3
Vivek maize hybrid 21	180.7	38	43	68	23.0
Vivek maize hybrid 23	219.7	43	45	70	25.0
Vivek maize hybrid 25	173.0	41	44	68	24.7
Vivek maize hybrid 33	185.0	40	46	71	22.7
Vivek maize hybrid 39	179.7	43	47	73	26.3
Vivek maize hybrid 43	165.3	43	47	68	24.7
Cmh08-156	209.0	48	51	78	27.0
Cmh08-239	230.0	47	50	74	24.7
Cmh08-337	252.3	49	52	78	28.7
Knmh-408710	206.7	49	54	79	27.3
Local check	231.7	68	73	93	22.0
LSD ($p=0.05$)	24.6	1.4	1.7	1.6	2.78

Table 6. Performance of Extra-early, early and medium single cross hybrid maize in Tripura during kharif 2012

Treatment	1000 grain weight (g)	Grain weight (g)	Grain yield (t/ha)
Peehm 5	220.0	0.22	3.19
Vivek QPM 9	186.7	0.19	4.15
Vivek hybrid 9	213.3	0.21	3.70
Vivek maize hybrid 21	186.7	0.19	3.56

Vivek maize hybrid 23	203.3	0.20	4.30
Vivek maize hybrid 25	260.0	0.26	4.07
Vivek maize hybrid 33	226.7	0.23	3.63
Vivek maize hybrid 39	246.7	0.25	3.70
Vivek maize hybrid 43	243.3	0.24	3.70
Cmh08-156	288.3	0.29	4.52
Cmh08-239	353.3	0.35	5.11
Cmh08-337	240.0	0.24	4.74
Knmh-408710	290.7	0.29	4.30
Local check	160.0	0.16	1.11
LSD ($p=0.05$)	15.33	0.015	0.65

Effect of land configuration and FYM on productivity of post rainy season maize.

Rabi (post rainy season) maize is a new hope for crop intensification in Tripura. After harvest of *kharif* season crops like green gram, blackgram, early sown upland rice etc., maize crop can be grown in residual stored moisture with life saving irrigations in *rabi* season because water scarcity is a major problem during *rabi* season. *Rabi* maize sown on 30 September in Agronomy Farm of ICAR, Tripura centre under broad bed and furrow system with 10 tonnes FYM/ha gave higher plant growth, dry matter accumulation and lower weed population, which indicate the higher crop growth that ultimately may give more yield of maize. Broad bed and furrow method of planting produced significantly higher yield as compared to flat bed method, which was on par with ridge and furrow method of planting (Fig 2). Application of FYM @ 10 t/ha produced significantly more yield as compared to other treatments (Figure 4). Hence, growing of maize on broad bed and furrow system with FYM application had gave more yield compared to other methods of planting.

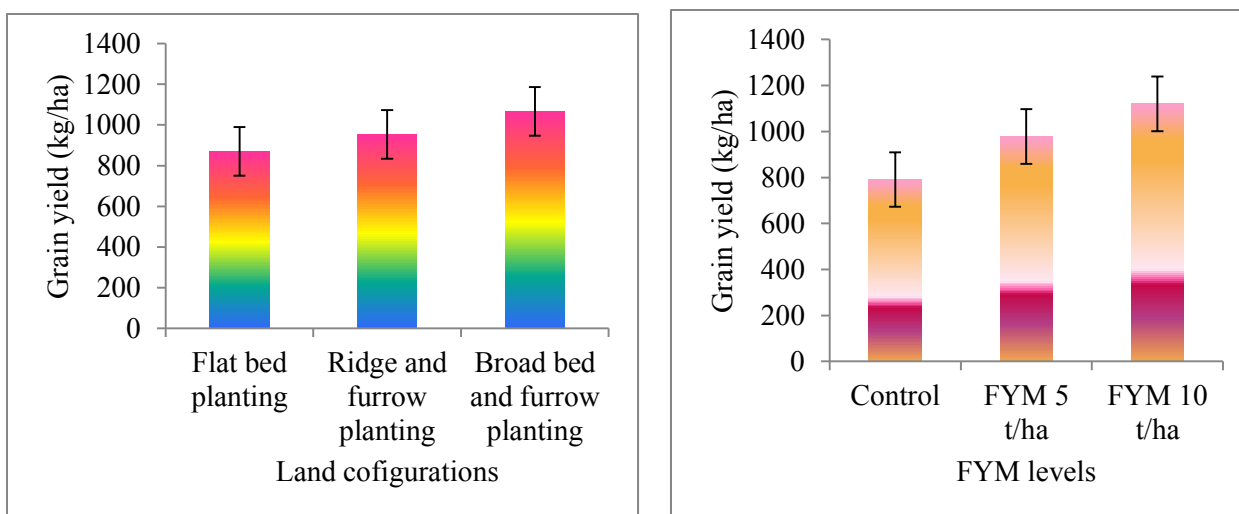


Fig 2. Effect of land configuration and FYM on productivity of post rainy season maize. Standard error bar indicated the CD values

Impact of various resource conservation measures on maize and soil health

A field experiment was conducted to evaluate impact of conservation tillage on productivity of maize. The experiment consisted of five treatments: NT/zero tillage (ZT), ZT + Live mulch (ZT+LM), reduced tillage (RT), RT + live mulch (RT+LM) and conventional tillage (CT). The maize crop was sown on 8th April at 60 x 30 cm spacing. The approximate fifty percent residue of previous crop was left on field as mulch in the entire ZT and RT plots. In treatments, where live mulch was used, the two rows of cowpea variety *kasha kanchan* were sown in between of two rows of maize. The crop was harvested on 27th June 2015. The results revealed that, maize grown under reduced tillage system with live mulch of cowpea produced significantly higher yield as compared to ZT, ZT+LM, RT and CT (Fig 3). The study suggested that cultivation of maize under reduced tillage condition with live mulch of cowpea is beneficial to the farmers for enhancing their productivity and income.

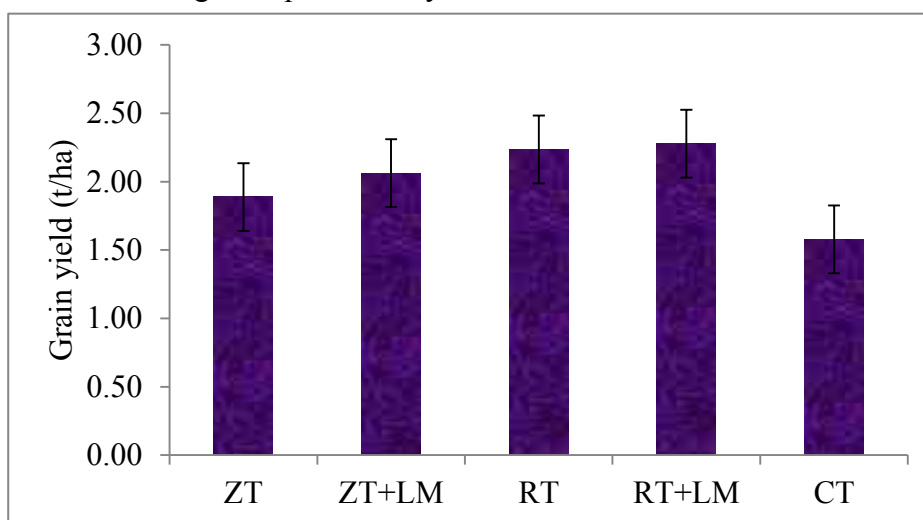


Fig 3. Effect of tillage and live mulch on grain yield of maize

The earthworm live weight was significantly higher under ZT+LM and ZT as compared to CT (Fig 4). The higher live weight of earthworm under ZT based plots indicated higher organic matter.

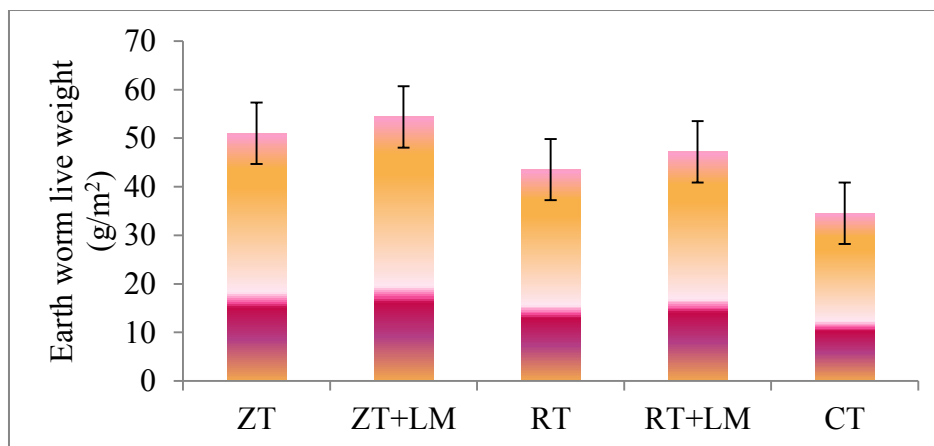


Fig 4. Effect of tillage and live mulch on earthworm live weight

In another study at ICAR, Lembucherra, Tripura, 6 tillage based resource conservation measures viz. conventional tillage with flat bed planting (CT-FB), conventional tillage with ridge and furrow planting (CT-RF), conventional tillage with raised bed planting (CT-RB), no-till with flatbed planting (NT-FB), no-till with ridge and furrow planting (NT-RF) and no-till with raised bed planting (NT-RB) were tested. Green cobs yield of summer maize was 25.3–27.4% and field pea seed yield was 17.9–32.2% higher under NT-RF and NT-RB than CT-RF. Rainy season (*kharif*) maize grown under NT-RF recorded 12.66% less grain yield than the CT-RF. The NT-RB resulted in the maximum system productivity to the tune of 16.34 and 14.55 t/ha in 2012–13 and 2013–14, respectively. The average system productivity was 6.1% higher under systems than to CT systems. Net returns and benefit: cost ratios showed the similar trends as shown by system productivity. Under the NT-FB, soil organic carbon was 13.2% higher than CT-FB. However, the CT-RB recorded higher soil pH as compared to all the other treatments. The available nitrogen, phosphorus and potassium were higher with NT systems compared to CT systems (Yadav et al., 2015).

Constraints of maize production in Tripura

Pedo-climatic

- Poor soil fertility (low N, P, SOC, pH etc)
- Poor distribution of rainfall
- Undulating topography
- Frequent climatic aberrations (like flood, drought etc.)

Technological

- Lack of high yielding composite/open pollinated varieties.
- Non- adoption of Package of practices
- Lack of facilities for post-harvest processing
- Inadequate extension support
- Non-availability of quality seeds

Infrastructural

- No infrastructure for storage of quality seed of maize
- Inability to purchase modern agricultural implements
- Lack of irrigation facilities
- Non-availability of agricultural chemicals at the time of need
- Lack of mechanization

Economical

- High cost of agricultural chemicals
- Non-availability of timely credit facilities
- Non availability of labour during peak period
- Low selling price
- Non-availability of processing industries (Value addition)

Social

- Choice of rice as grain crop over maize
- Inadequate social awareness on maize
- Lack of skill on improve technologies

Opportunity of maize in Tripura

- About 81% TGA is under sloping and uplands where maize can be a potential crop.
- Maize has been an integral component of traditional jhum farming; hence farmers are well acquainted with crop.
- Maize has high potential as feed for cattle and poultry. High transportation cost contributes to exorbitant price of cattle and poultry breed when brought from other part of the country.
- Younger generation populations are very much attracted towards popcorn and baby corns.
- Baby corn and pop corns are also having high potential for entrepreneurship development.
- In addition to grain, maize stalks are also having high fodder value.
- Hybrid maize is having opportunity in the region both a food-feed crop.
- Maize more hardy than rice and also requires lesser water than other cereals and vegetables, thus contributes to environmental sustainability.
- In uplands/medium lands, maize can be promoted instead of rice for enhancing productivity and income.
- Adequate infrastructural facilities should be established for production of concentrate feed in the state with other ingredients like soybean, oilcake etc.
- Maize seed storage is a major challenge in the state due to high humidity and favorable temperature for pest and diseases. Hence, seed drier, quality storage facilities should be established.

Conclusions

Maize is having very good potential in upland and jhum land fields as pre-kharif and kharif season crop whereas in lowland it be a very good option after rice. Availability of quality seed of desired variety along with need based inputs may enhance area and productivity of crops substantially in the NER in general and Tripura state in particular. Maize has feed ingredient can

play a major role in income enhancement of farmers through availability of low-cost concentrate feed in the region. Maize-pulses (French bean/cowpea/black gram/pea etc.) and maize-oilseeds (Rapeseed/Mustard) are potential cropping system for efficient utilization of available resources. Integrated nutrient management involving locally available resources should be developed for location specific maize production in the region. Mechanization and post-harvest processing will have to play a major role for realizing the full potential from maize crop in the region and Tripura state. Finally, diversification/Intensification of maize based system along with need based location specific crop and soil management practices under both irrigated and rainfed ecosystems may enhance the productivity, profitability and resource use efficiency in the region as well as Tripura in changing climatic conditions.

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POTENTIAL OF MAIZE CULTIVATION FOR LIVELIHOOD IMPROVEMENT OF FARMERS OF ARUNACHAL PRADESH: STATUS, OPTION AND STRATEGIES

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Maize has its significance as a source of a large number of industrial products besides its uses as human food and animal feed. Diversified uses of maize for maize corn starch industry, corn oil production, baby corns, popcorns, etc., and potential for exports has added to the demand of maize all over world besides other commercial avenues. In India, maize is emerging as third most important crop after rice and wheat and is grown in 24 states which are Andhra Pradesh, Telangana, Arunachal Pradesh, Assam, Bihar, Gujarat, Himachal Pradesh, Jammu & Kashmir, Karnataka, Madhya Pradesh, Maharashtra, Manipur, Meghalaya, Mizoram, Nagaland, Orissa, Punjab, Rajasthan, Sikkim, Tamil Nadu, Tripura, Uttar Pradesh and West Bengal. In India, maize is cultivated in 8.7 m ha (2010-11) mainly during *Kharif* season which covers 80 per cent area and contributes nearly nine per cent to the national food basket and more than Rs. 100 billion to the agricultural GDP at current prices.

In Arunachal Pradesh, out of the total geographical area 8374 '000 ha, the net sown area is 211 '000 ha and only 5000 ha is under maize with a production and productivity of 80000 MT and 417 kg/ha (2009-2010). The productivity is far below the national average due to rainfed cultivation and predominance of low yielding local cultivars. The cause of low maize productivity is absence of location specific varieties, low use of organic manure and unfavourable climatic conditions particularly during the pre-*Kharif* and post-*Kharif* seasons when heavy rain with turbulent storms occur.

Significance

In the world, maize is emerging as the third most important crop after rice and wheat due to its high nutritional value. Maize has high level of starch and also valuable proteins and oil. Depending on the variety, maize may contain a number of important B vitamin, Vitamin C and provitamin A. Maize is also rich in P, Mg, Mn, Zn, Cu, Fe and Se, and has small amount of K and Ca. Maize is a good source of dietary fiber and protein while being low in fat and sodium. However maize is naturally deficient in lysine and tryptophan which are two of eight amino acids regarded as essential for humans. Thereby, maize and maize products can improve the nutritional status of finance poor tribal farmers of Arunachal Pradesh. Arunachal Pradesh is known for diversity in maize germplasm. A report by Pandey and coworkers (2016) showed that maximum collections of accessions in parenthesis were made from Arunachal Pradesh (1013) throughout the county. In district level maximum accessions were from West Kameng (215) followed by West Siang (187) and East Siang (183) districts. Maize requires an optimum temperature of approximately 30⁰C. Coincidentally, this temperature (30⁰C) is achieved in the

north-east hill (NEH) region and north-western Himalaya during the summer (pre-monsoon) season. Maize crop is known to have a wide adaptability to different climatic conditions. Therefore, the cultivation of maize in Arunachal Pradesh spans from an altitude of 200 m msl to 3000 m msl.

Status of Maize cultivation

In Arunachal Pradesh, maize is cultivated mainly for food and feed purpose. Maize crop is cultivated in Jhum mostly during the summer or pre-kharif season under rainfed condition. In some districts maize is grown as rabi crop during September-October. Sowing of maize is done by random dibbling at a depth of 20-30 cm depth. The intercultural activities like weeding are done as and when required. The crop is completely rainfall dependent. Maize is commonly crop grown after rice. Likewise, some of the major cropping systems practiced in Arunachal Pradesh are: Maize- Rice –Mustard, Maize- Rice- Potato, Maize- Rice- turmeric/ginger. Intercropping of maize with cowpea, frenchbean, blackgram, soyabean and local herbs is also a common cropping system in Jhum land. The common varieties grown are Novjot, Nabin in eastern Arunachal, RCM-1-75, RCM-1-76 (early maturing) in Western Arunachal and Zero local, Tapoli and Tago local in central Arunachal.

By default the cultivation of maize is done organically without any chemical inputs. However the continuous utilization of the land resources without replenishment of soil fertility will cause soil fertility deterioration. Till date the soils of Arunachal are almost virgin with 4-5% soil organic matter. However, faulty traditional practices like jhum without contour bunding or terracing will render it unfertile in the coming years as a consequence of soil erosion and surface runoff.

According to the data of last five years it is observed, area under maize cultivation, production and productivity is gradually increasing in Arunachal Pradesh (Table 1). According to the statistics estimated, though, the area under maize cultivation was highest in Lohit district, the highest production and productivity was observed in East Siang District (Table 2).

Table 1. Area and Production of Food (Area in hectare and Production in MT)

Crop	2005- 2006		2006- 2007		2007- 2008		2008- 2009		2009- 2010	
	Area	Prod.	Area	Prod.	Area	Prod.	Area	Prod.	Area	Prod.
Maize	44450	68000	46450	72000	47700	74500	48100	76000	50000	80000

Table 2. District wise distribution of maize area, production and productivity under rainfed condition during summer in Arunachal Pradesh.

District	Year	Area (ha)	Production('000 t)	Productivity (kg/ha)
East Siang	2006-10	2883	6.44	2235

West Siang	2006-10	2859	4.106	1440
Upper Siang	2006-10	1803	2.706	1499
Upper Subansari	2006-10	650	1.33	2050
Lower Subansari	2006-10	650	1.33	2050
East Kameng	2006-10	2453	3.273	1315
West Kameng	2006-10	2453	3.273	1315
Papumpare	2006-10	2350	4.5	1800
Lohit	2009-10	8024	10.03	1.25
Tawang	2006-10	695	6.9	1006
Anjaw	2006-10	3995	3.995	972
Tirap	2006-10	2453	3273	1315

Constraints

Globally, maize is known as queen of cereals because it has the highest genetic potential among the cereals. But, maize is a heavy nutrient feeding crop which can exhaust the soil fertility. Thereby, several constraints identified in maize production of Arunachal Pradesh are given below under specific heading.

i. Agronomic: Random method of sowing is un-economic and causes problem for intercultural activities. Therefore, ICAR, Basar have recommended sowing of seed in row of 65-75 cm apart with seed to seed distances of 20-30 cm in “Scientific Maize Cultivation in Arunachal Pradesh” folder.

ii. Plant genetic and breeding: Scarcity in availability of high yielding and stress tolerant variety in Arunachal Pradesh.

iii. Plant disease and pest: The climatic condition of Arunachal Pradesh experiences unseasonal rains which causes outbreak of pests and diseases.

iv. Soil degradation and problems: Here lies the foremost constraints in low maize production and productivity due to Jhum farming without soil conservation and soil fertility management in Arunachal Pradesh. Maize requires an optimum pH of near neutral for its growth and development. In contrary, the average soil pH of Arunachal Pradesh ranges from 3-6. Thus, liming of soil which is a soil amendment strategy, recommended for acid soil is almost nil. This predicament is due to poor financial status of tribal farmers. Again, as maize is cultivated under rainfed condition, the field capacity requirement of crop plant may not meet during the hot summer months.

v. Marketing, processing and value addition: The absence of proper marketing channel is a major drawback for the low maize productions. In addition, the absence of processing industries and value addition strategies also adds to the plight of maize production in Arunachal Pradesh.

Scope of Maize Production

It is a common observation that the terrace or plain rice land use is mostly left fallow after harvest. Rice- fallow land use provides a scope for vertical crop intensification and diversification by growing maize. Consequently, it will increase cropping intensity percentage and soil fertility status. Other than food and feed, maize has high potential in post-harvest processing and value addition. As there are many self-help groups, it can become an income generation sector. This sector of agricultural has an immense potential to improve revenue generation of the farmers. Lack, of private industries or factories have made youths of Arunachal Pradesh solely dependent on governments job. Thus, maize production and post-harvest processing can solve the problem of employment. According to literature maize requires soil K in heaviest amount and soils of Arunachal Pradesh are in the high soil available K. This prevalence of high soil available K is a scope for increasing production maize with efficient agricultural management practices. As seen in the above paragraph, the vase and diverse maize accession number is a potential scope in generating location specific varieties.

Strategies of maize productivity improvement

In Arunachal Pradesh, maize is cultivated mostly in small area for own consumption or local market. No standard package of practices is followed by farmers practicing Jhum. Therefore, a paradigm maize production package of practices is essential to improve the productivity. The maize land races in Arunachal Pradesh have low crop productivity. Thereby, ICAR, Basar have recommended some improved varieties that are high yielding and stress tolerant like Tapoli, Sago local, DA 618, Vivek hybrid, Vivek QPM-9 etc. Harvesting time and storage methods are equally important to improve the shelf life of the crop. Corn cob harvesting can begin when the kernel moisture reaches 30% or 95% mature. If the moisture content is too high, many of the kernels will rupture before breaking away from the cob and longitudinal cob breakage may increase. If the moisture content is too low, field losses due to lodging and dropped ears will be increased and more kernels will be damaged when the cylinder bar strikes them. The remaining biomass of maize plant can be used as fodder. The cob should be sun dried and shelled when kernel moisture content is below 30% but to store it safely, the moisture must be reduced to 14-15%. Traditionally, the maize cobs are hung above the fireplace to prevent spoilage of cob. However, this procedure is not practical for huge quantity. Alternatively, dried cobs can be stored in dry store bin with neem leaves to protect them from storage pest.

Jhum cultivation has slope percentage more than 30% which leads to exhaustion of soil fertility as a consequence of top soil runoff, soil erosion and landslides. Generally, Jhum lands are located adjacent to the forest. These dense forests serve as breeding ground for many diseases and pests which cross over to the jhum land infesting the crops. Therefore, implementing a preventive measure like maintaining scientific buffer zone planted with hedges can reduce the intensity of disease and pest infestation. Landslide, erosion and runoff are ubiquitous casualty. Thereby soil conservative measures like contour bunding and terracing is imperative to prevent

soil loss. In addition, soil productivity can improve with integrated soil nutrient managements and soil amendments approaches. Application of manures, vermicompost, biofertilizers and different cakes play important role in organic maize production and productivity for supplementation of nutrition. Apart from that green manuring [*Crotalaria juncea* (sunhemp), *Sesbania aculeata* (dhaincha)], green leaf manuring [*Leuceana leucocephala* (subabul), *Tephrosia*] could be another alternative for nutrient supplementation in organic production system. Maize requires a regulated and assured supply of nutrients particularly N throughout its growing period right from seedling stage to grain filling stage. ICAR RC NEH, Arunachal Pradesh Centre, Basar have recommended application of compost or FYM @ 5t/ha + N:P:K of 60:40:40 in general and N:P:K of 90:40:40 for hills under rainfed condition. Similarly, ICAR Barapani recommends application of well-decomposed FYM @ 15 t/ha applied 20 days before planting along with 150 kg rock phosphate. Neem cake can also be added @ 150 kg/ha to the field for effective control of soil-borne insect pests. Application of FYM @ 10-15 t/ha + vermicompost @ 2.5 - 5.0 t/ha either alone or in combination as basal dose will also meet the nutrient needs.

Climate change and global warming is a global issue that is observed in Arunachal Pradesh. Consequently, the farmers face losses due to shifting of cropping season or unseasonal rains. Therefore, agrometeorology field unit of ICAR RC NEH, Basar provides advisory weather based agromet advisories to 16 districts of Arunachal Pradesh on Tuesday and Friday through mobile *sms*, *whatsapp* and *bulletins* to over 2 lakhs farmers. The main emphasis of the service is to collect and organic climate/weather, soil and crop information and to amalgamate them with weather forecast to assist farmers in taking appropriate management decisions. This service provide mid range forecast to save the inputs like labour, irrigation, pesticides, fertilizers etc. when specifically tailored weather support is available as per need of farmer, it contribute greatly towards making short term adjustment in the daily farm operation. The seasonal weather outlook also provide guidelines for long-range or seasonal planning and selection of crops and varieties most suite to anticipated weather conditions

Processing and Value addition

Globally, maize is the most important coarse grain cereal and well known as “poor man’s nutricereal” due to presence of high content of carbohydrates, fats, proteins, and some of the important vitamins and minerals. On the basis of its unique characteristics and nutritional composition specialty, corn is classified into quality protein maize, baby corn, sweet corn, pop corn, green eared corn, high oil corn, etc. Corn has diverse end uses and a number of value-added products can be prepared from it. Maize food products can be processed at home on a small local scale as well as on a larger industrial scale, transforming the raw material into food products. Some of the products are more suitable for commercial trade because they require further processing or provide convenience and extended shelf life, while other products should be consumed immediately after production. Initially, processing of maize cob starts after

harvesting, i.e. sun drying and shelling. Processing and value addition is an asset to the farmer producer. Thereby, harnessing these resources judiciously will help increase the farmer's income. Maize can be consumed as vegetables, popcorn, corn snacks, flour, corn flakes, pasta, vadi, vermicelli, bread, cookies, cake, raab, papdi, laddoo, halwa, burfi, kheer, sattu, cheela, jajaria, rabodi etc. The value-added products prepared from corns are traditional foods, infant foods, health foods, snacks and savory, baked products, etc. Apart from these products, maize is used to prepare industrial products such as starch, specialty chemicals, ethanol, refined corn oil, sorbitol, cake mixes, candies, carbonated beverages, and cosmetics. Maize value addition and processing industry provides an opportunity for many self help groups registered under Government of Arunachal Pradesh. Some of the processing and value addition products are given in details below:

Processing of Maize

Milling of maize is a process that separates the grain into distinct physical components based on size and weight. There are two kinds of milling. They are dry and wet milling operation.

Wet-milling process: The corn wet-milling process breaks corn kernels into corn oil, protein, corn starch, and fiber. The components are separated by physical characteristics, mostly by weight and size. Water is needed as it is a wet process and it works as separation/carrier agents in washing steps. Therefore, this process can be considered as having high capital cost. The only chemical use in this process is aqueous sulfur dioxide solution, which is used in the steeping process. The corn is soaked in this solution to soften the kernel so that the oil in the germ will not contaminate other products and is easy to separate.

Dry-milling process: Dry milling is mainly focused on corn based products for human and animal consumption, or utilized during fuel ethanol production. The main objective of the dry milling process is to separate the endosperm, which is mainly composed of starch, from the germ and pericarp fibers as much as possible. Milling of maize is a process that separates the grain into distinct physical components: the germ, flour, fine grits, and coarse grits. This process includes a number of unique features like no use of chemicals, maximizing surface area of solids for processing, resource pulping, minimal water use, if any (short tempering), water is not used as a separation agent, low capital cost. However, it has, lower separation compared to wet milling, lower concentration of starch, protein, fiber, and oil relative to wet milling.

Value addition of Maize

Baby corn: Baby corn is the ear, harvested young when the silks have just emerged and no fertilization has taken place.

Sweet corn: In sweet corn, the taste of kernels is much sweeter than normal corn.

Popcorn: In popcorn when kernels are heated, they explode and produce large puffed flakes (popping).

Pasta/vermicelli: Pasta is dough made from fine corn, extruded or stamped into various shapes and typically cooked in boiling water. Corn pasta/vermicelli contains a variety of beneficial phytochemicals that act as antioxidants to the body. It has high fiber content which is vital for overall digestive function. It is remarkably rich in antioxidants and helps to slowing down the process of aging. The essential amount of fiber in corn helps in scrapping off dangerous cholesterol (LDL) in the body and improves the general health of heart.

Bread/ Cookies/ Cake: Bread is made of corn flour, water, and yeast mixed together and baked.

Sattu: Sattu is prepared by dry roasting corn grains in an iron vessel filled with sand. Afterwards they are sieved and then ground to a fine flour

Conclusion: Maize land races have adapted to the various agro-climatic zones of Arunachal Pradesh providing an easily accessible platform for maize varieties improvement. Apart from the constraints, maize processing and value addition have tremendous potential to improve farmers income and production. Therefore, with paradigm scientific cultivation approach, this region has tremendous scope for maize production and productivity improvement.

STATUS AND STRATEGIES OF MAIZE CULTIVATION IN NAGALAND

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Globally, maize is the 3rd most important cereal crops next to wheat and rice and contributes to the food security in many developing countries of the world. The crop assumes significance not only as food crop but also its use as animal feed and industrial products, baby corn etc. Globally maize is cultivated in an area of 180 m ha with 967 m t of production and 5.6 t/ha productivity. From about 12 million tons of production in 2000, the country produces about 26 million tons today. Maize occupies about 8.7 m ha with a productivity of 2.5 t/ha. The productivity of maize in the country is about half of the world productivity. It is estimated that India will require 45 mt of maize by 2022. In India, 15 million farmers are engaged in maize production. During the last five years, maize consumption has recorded a CAGR of 11 %. Maize is a multifaceted crop today due to its use for production of starch, ethanol, food processing, dairy, poultry, meat and industrial uses besides its traditional uses. Poultry feed alone accounts for 47 % of total maize consumption in the country. Internationally maize trade exceeds rice trade. USA, Brazil, Argentina and India are the major maize exporter while, Japan, South Korea and Mexico are the major importer of maize. The crop is gaining immense popularity due to its wider adaptability to climatic variation and its resilience to climatic stresses. Among the north eastern states, Nagaland accounts for the highest maize acreage (68.5 thousand ha), production (134.3 thousand tons) and productivity (1958 kg/ha). The productivity of maize in the region is far below the national (2.5 t/ha) and global productivity (5.6t/ha). There is tremendous scope to increase the maize productivity in the country as well as in the region. Maize is grown in almost all the districts in Nagaland however, Tuensang, Zuneboto, Phek, Kephrie are the major maize growing districts. The crop is mostly cultivated during rainy season. Among the districts, the highest productivity is in the Dimapur district followed by Wokha.

Table 1. Area(,000ha), Production(,000t) and Productivity(kg/ha) of Maize in N.E.States (2011-12) .

State	Area	Production	Productivity
Arunachal Pradesh	46.5	68.5	1473
Assam	21.3	15.3	719
Manipur	24.9	45.9	1856
Nagaland	68.5	134.3	1958
Meghalaya	17.4	26.5	1529
Mizoram	6.9	8.4	1214
Sikkim	4.0	66.2	1657
Total	189.5	365.1	1486.0

Source: Basic Statistics of N.E.India (2015)

Table 2. District wise Area, Production and productivity of maize

District	Area (ha)	Production (t)	Productivity (kg/ha)
Kohima	4610	9100	-
Phek	8820	17400	-
Mokokchung	3930	7750	-
Tuensang	10130	20070	1670
Mon	5600	11040	-
Dimapur	6730	13270	1970
Wokha	5230	10340	1800
Zunheboto	10090	19950	1702
Peren	3100	6120	1680
Kiphrei	7550	14910	-
Longleng	3030	5990	-

Why Maize Cultivation?

The maize cultivation is gaining popularity in different parts of the world as well as at national level due to its associated advantages. Some of the advantages are-

- Higher Production per unit area
- Tremendous demand not only as food but also as feed
- Enhanced Income
- Employment generation and value addition
- For nutritional security
- Adaptability to varied soil and climatic conditions
- Rising demand for domestic use and export depotentiality

Constraints of Maize cultivation

Jhuming is a common practice followed by the farmers of Nagaland, especially in the high altitude areas. It is mostly grown under Jhum land and terraced area .Some of the major constraints of maize cultivation in Nagaland are ---

- Lack of availability of quality seed (composite/hybrid)
- Cultivation under rainfed conditions (In India, only 15 % area is under irrigation)
- Lack of adoption of appropriate management practices
- Emergence of biotic and abiotic stresses
- Shortage of labour which affects timely filed operations
- Lack of Mechanization
- Lack of marketable surplus
- Lack of transportation
- Lack of organized market
- Lack of PHM

- Lack of value chain
- Lack of appropriate storage facility (5-7 % Maize is lost due to lack of proper storage in India)
- Lack of appropriate capacity building programme

Strategies

- Ensuring quality seed at Farmer,s easy reach
- Popularizing cultivation of single cross hybrid
- Organizing seed producer groups/participatory seed production
- Provisioning PPP opportunities in seed production
- Creation of storage infrastructure
- Ensuring public procurement with appropriate MSP
- Technology infusion for bridging the yield gaps
- Provisioning Micro-irrigaion (preferably solar based)
- Encouraging in-situ soil moisture conservation
- Popularizing Resource conservation practices
- Provisioning credit facilities
- Ensuring Crop insurance
- Appropriate procurement policy at suitable MSP
- Provisioning appropriate dryers and creation of infrastructures

CLIMATE CHANGE IN THE NORTH EAST AND ITS LIKELY IMPACT ON MAIZE (*ZEA MAYS L.*) PRODUCTION

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India's North Eastern Region consists of eight states—Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, and Tripura—occupying 262,179 square kilometres and with a population of over 45.58 million (Census 2011) which is 3.77% of India's population. The region falls under high rainfall zone (>2000 mm annual rainfall) and is characterized by having difficult terrain, wide range of slopes and elevations, varied land tenure system, ethnic diversity, diverse food habit and cultural practices. Agriculture is the mainstay of the economy of northeast India, where more than 80 percent of the total population is rural. *Jhum* (shifting) cultivation is the predominant land use system in the hilly states of the region covering an area of 0.76 million hectares. The *jhum* is not only a farming practice in the north east hill region, but a way of life of the tribal farmers. Poor soil health (soil acidity, toxicity and deficiency of nutrients etc.) is often a yield limiting factor for crop production in the north east and increases the potential for runoff, erosion and other environmental losses, as well as drought. These problems are anticipated to become more severe with climate change.

Climate change in north east India:

There have been some conspicuous changes in temperature as well as rainfall pattern in northeast India over the past century. The annual mean maximum and mean temperature in northeast India during 1901-2003 has increased significantly by a rate of 1.02⁰C and 0.60⁰C/100 years, respectively (Deka et al. 2009). Atmospheric temperature in the region is further projected to rise by approximately 3⁰C to 5⁰C during the latter third of this century (Cline, 2007). There is reduction in the annual as well as the monsoon rainfall over the years in the north-east. In the recent times, the alarming deficits in annual as well as monsoon rainfall resulted in severe droughts across the hill region. The shift in the climatic scenario and lack of mitigation strategies with the farmers makes the challenges in agriculture further complex. Since 80% of the crop area is under rainfed, future climate change and variability will potentially impact agricultural production pattern in the region (Ministry of Environment and Forests Report 2004, GOI). Results of the recent study (Ravindranath *et. al.*, 2011) indicates that majority of the districts in north east, presently and in future, are subjected to climate induced vulnerability. The monsoon rainfall decreased by 4.4-24.6% in the region except Sikkim, Meghalaya and Manipur (4.1- 10.5% ↑). During last five years (2011-2015), the gain in monsoon rainfall further increased in Manipur (29%) and Meghalaya (35%) over 1971-2010 (40 yrs.). Monsoon rainfall decreased further in Mizoram (-27%), Sikkim (-18%) and Tripura (-7%) during 2011-2015 (5 yrs.) over 1971-2010 (40 yrs.). Annual rainfall also followed similar pattern in the NE states. Gain of annual rainfall at Manipur and Meghalaya were 11 and 21%, respectively during 2011-2015 over

1971-2010. There is a sign of improvement in Arunachal Pradesh but deteriorating in Sikkim (-10%) and Tripura (-13%). Maximum temperature showed an increasing trend from 1985 (24.3⁰C) to 2009 (26.5⁰C), whereas minimum temperature showed irregularities with slight reduction in Umiam, Meghalaya. The annual mean maximum temperatures in the region are rising at the rate of +0.11⁰C per decade.

Regional Climate Model (RegCM3) projected an increase in the annual mean surface temperature by about 0.64 ⁰C in the 30 years from 2011 to 2040 and by 5.15 ⁰C at the end of the century (2071–2100). It also projected an increase in annual mean precipitation by about 0.09 mm/day in the near future and by 0.48 mm/day at the end of the century (Das et al., 2012).

Likely impact of climate change on maize productivity

Maize being one of the important crops cultivated by hill farmers of the North Eastern Region both as *kharif* and *rabi* crops. The productivity of the crop in North East is reported to be very low (<1.5 t/ha) as compared to the national average (2.5 t/ha). The livestock, poultry and fishery sectors in the North East are growing at a faster pace resulting more demand for maize based livestock and poultry feeds. Increasing local demand for maize grain necessitates enhancement of productivity of the crop in the region. However, future climatic change is likely to have substantial impact on maize production depending upon the magnitude of variation in rainfall, temperature, drought etc. Even conservative target of 2⁰C global mean warming would imply a reduction of 8 to 14% in global maize production with only a modest beneficial effect of enhanced CO₂ on the C4 crop. Without CO₂ fertilization, effective adaptation, and genetic improvement, each degree-Celsius increase in global mean temperature would, on average, reduce global yields of maize by 7.4% (Chuang et. al., 2017).

In the context of present and future scenario of temperature rise in the region, it is expected to have significant impact on productivity of maize crop. Study suggest that each 1⁰C increase in temperature above optimum (25⁰C) results in a reduction of 3 to 4% in grain yield (Shaw, 1983). Patidar (2015) observed that an increase in temperature by 1⁰C resulted in 9.5% reduction in yield. Simulation study using APSIM (*Agriculture Production System Simulator*) model showed that increase in temperature causes significant reduction in grain and biomass yield. The increase in temperature decreases the crop duration that could probably be the major reason for significant reduction in crop yield. One degree increase in temperature decreased the duration of crop by 4.3 days. It was also observed from the simulation study that increasing the temperature by 5⁰C, decreased the duration of maize crop by 13 days (Patidar, 2015). Rise in temperature above 30⁰C results in poor synchronization of flowering (asynchrony) due to mismatch between silking period and anthesis/tasseling. Pollen shedding starts much ahead of silks emergence. Further rise in temperature reduces the pollen viability and silk receptivity resulting in poor seed set and reduced yield (Shreshta *et al.*, 2014). The major effect of high

temperature is embryo abortion, which is related to the inhibition of photosynthesis that results in reduction in assimilates available to developing kernels.

The best soils for maize are those that are neutral or near-neutral in pH. More than 80% of NE soils are acidic in nature and aluminium toxicity and Ca, Mg, P, B and Mo deficiency are the major soil related constraints for production of crops/fodders in these soils. In areas where climate is expected to become warmer and wetter, microbial activity in soil may increase, resulting increased soil air CO₂ concentrations leading to production of more carbonic acid in soil. Research finding reveals that a rise in average soil temperature by 2⁰C would result in an increase in soil respiration by 22%. High carbonic acid concentration and increased rainfall events result in intense leaching of basic cations from the soil system which implies more acidification of soil. Considerable grain yield reductions of maize under low soil pH have been reported in numerous studies. Dewi-Hayati *et al.* (2014) reported that grain yield reduction in acid soils varied from 2.8 to 71%, whereas Tandzi *et al.* (2015) found reduction in maize yield up to 69% due to soil acidity problem. The variation in yield reduction under low soil pH is based on the level of acidity in the soil, the agro-climatic conditions of the environment, and the genetic potential of maize genotypes. Improving grain yield under acidic soil conditions is a major objective of maize breeding programs in many regions of the world.

Maize production of North East is largely dependent on the monsoonal rainfall. Rainfall influences maize growth during monsoon season by influencing soil moisture availability. Excessive soil moisture is one of the major limiting factors for maize productivity in tropical and subtropical regions. Climate change vulnerability profiles for North East India (Ravindranath *et al.*, 2011) showed that in Tripura, Mizoram, Manipur, parts of Meghalaya and Nagaland, the flood magnitude is likely to increase by about 25% in the future compared to the present. Arunachal Pradesh, Assam, Sikkim and parts of Meghalaya are likely to experience floods of lower magnitude (about 5–10% less) in future. Occurrence of flood will seriously affect maize productivity in the North East. Among various abiotic stresses, excessive soil moisture (water logging), caused by flooding, water stagnation or a high water table is one of the most important constraints for maize production and productivity in Asia Pacific region. In Southeast Asia, 15% of total maize growing areas are greatly affected by waterlogging problems, causing 25-30% losses of maize production every year (Rathore *et al.* 1998). Water logging is becoming one worldwide abiotic threat in many agricultural areas (Ghassemi *et al.* 1995). High intensity rainfall in a short span of time due to climate change can lead to forming waterlogged soils for an extended period. Maize plants will be severely damaged after a short period of waterlogging, and large areas of maize will be lost even after a quick inundation.

The numbers of drought weeks during monsoon months shows an increasing trend in Arunachal Pradesh, parts of Assam, Meghalaya, Mizoram, Tripura and Manipur, to the tune of about 25% increase in future. A few districts in Assam, Nagaland, Meghalaya and Mizoram show improvement in drought situation during the onset of monsoon. Many parts of the Brahmaputra basin show a tendency of extreme soil moisture stress during monsoon months,

which is likely to lead to moderate to extreme drought condition (Ravindranath et al., 2011). A normal maize crops require 700 mm rain to complete the life cycle with good production. Increase in water beyond 700 mm and lower than that reduces the crop growth and yield. Each millimetre of water produces 15 kg of kernels and total 450–600 mm is needed across the whole season (Du Plessis 2003). Total 250 l water is consumed by maize plant till maturity (Du Plessis 2003). In maize, developmental stages starting from germination to harvest maturity including seedling establishment, vegetative growth and development and reproductive growth stages are very much prone to drought stress. Pollination is most critical growth stage for water requirement. Grain filling and soft dough formation are most sensitive to water deficiency, whereas, pre-tasseling and physiological maturity are relatively insensitive to water deficiency. Drought stress during vegetative growth stages especially during V1–V5, reduces growth rate, prolong vegetative growth stage and conversely duration of reproductive growth stage is reduced (Pannar, 22012).

Conclusion:

It is now well understood that climate variability and climate change are reality. Therefore, assessment of the impacts and vulnerability of agricultural sector and comprehensive understanding of adaptation options is essential. Development of technologies which are resilient to stress is the way towards climate resilient agriculture. Appropriate transfer of climate smart technologies will certainly help to the farmers of north east in sustaining their livelihood under the changing climate of the region.

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SIGNIFICANCE OF BABY CORN AND SWEET CORN IN NORTH EASTERN INDIA: CHALLENGES AND OPPORTUNITIES

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Specialty corns have several health benefits along with a delicious taste of their own. Specialty corn types (QPM, sweet corn, popcorn, baby corn) are rich in essential nutrients. Further nutritional improvement using traditional and modern approaches can be the best option for ensuring nutritional vitamin A, etc. will increase levels of several micronutrients that are insufficient to meet daily requirements at no additional cost. These specialty maize types must be grown in time isolations of 10-15 days or in space isolation of at least 250 meter for getting desired quality specialty maize. It means there is need to go for the baby corn and sweet corn village clusters for making quality production in NEH regions. In this chapter, quality of these specialty maize and their production technology along with challenges and opportunities discussed in details with special reference to NEH regions of the India.

Baby corn is the ear of maize (*Zea mays* L.) plant harvested young, especially when the silks have either not emerged or just emerged, and no fertilization has taken place, depending on the cultivar grown. The dehusked young ears of baby corn can be eaten as vegetable, whose delicate sweet flavour and crispiness are much in demand. Importantly is free from pesticides and its nutritional value is comparable to popular vegetables like cauliflower, cabbage, tomato, eggplant and cucumber. It's by products such as tassel, young husk, silk and green stalks provide good cattle feed.

What baby corn is?

- Unfertilized cobs
- 6-11 cm long; 1.0-1.5 cm thickness
- Creamish to very light yellow
- Regular row arrangement
- Harvested 1-3 days silk emergence.
- 3-4 crops in a year
- Uses: salads, chutney, vegetables, Pickles, soup and several recipes, corn pakoda, etc.

Baby corn is a young finger like unfertilized cobs with one to three centimeter emerged silk preferably harvested within 1-3 days of silk emergence depending upon the growing season. The desirable size of baby corn is 6 to 11 cm length and 1.0 to 1.5 cm diameter with regular row/ ovule arrangement.

The most preferred colour by the consumers / exporters is generally creamish to very light yellow. Baby corn is nutritive and its nutritional quality is at par or even superior to some of the seasonal vegetables. Besides proteins, vitamins and iron, it is one of the richest sources of phosphorus. It is a good source of fibrous protein and easy to digest. The nutritive value of the baby corn is comparable with most of the 3 common vegetables (Table 1). It is good source of carbohydrate, thiamine and phosphorus compared to other vegetables.

Table: 1. Nutritive value of baby corn in comparison to common vegetables (per 100 g of edible portion)

Nutrient	Baby Corn	Cauliflower	Cabbage	Tomato	French Bean	Lady's Finger	Radish	Brinjal	Spinach
Moisture content (%)	89.10	90.80	91.90	93.10	91.40	89.60	94.40	92.70	92.10
Carbohydrates (g)	8.20	4.00	4.60	3.60	4.50	6.40	3.40	4.00	2.90
Protein (g)	1.90	2.60	1.80	1.90	1.70	1.90	0.70	1.40	2.00
Calcium (mg)	28.00	33.00	18.00	20.00	50.00	66.00	50.00	18.00	73.00
Phosphorus (mg)	86.00	57.00	47.00	36.00	28.00	56.00	22.00	47.00	21.00
Iron (mg)	0.10	1.50	0.90	1.80	1.70	1.50	0.40	0.90	10.90
Thiamine	0.50	0.04	0.04	0.07	0.08	0.07	0.06	0.04	0.03
Riboflavin	0.08	0.10	0.11	0.01	0.06	0.01	0.02	0.11	0.07
Ascorbic Acid	11.00	56.00	12.00	31.00	11.00	13.00	15.00	12.00	28.00

Baby corn is nutritive and its nutritional quality is at par or even superior to some of the seasonal vegetables. Besides proteins, vitamins and iron, it is one of the richest sources of phosphorus. It is a good source of fibrous protein and easy to digest (Table 2). It is the most "safe" vegetable to eat as it is almost free from residual effects of pesticides as the young cob is wrapped up with husk and well protected from insects and diseases.

Table 2: Nutritional composition of baby corn on dry matter basis

Particulars	Baby Corn Hybrid (HM-4)
Moisture [g/100g]	7.37
Crude protein [g/100g]	10.04

Crude fat[g/100g]	4.43
Crude fibre[g/100g]	2.4
Ash[g/100g]	1.34
Total carbohydrates	81.97
Energy[Kcal/100g]	375.67
Total soluble sugars [g/100g]	0.14
Calcium [mg/100g]	17.76
Phosphorous[mg/100g]	197.89
Iron[mg/100g]	2.73

(Source: Kawatra and Sehgal, 2007)

It can be cultivated round the year therefore, three to four crops of baby corn can be taken in a year. Cost of cultivation of baby corn in India is lowest in the world therefore; India can become one of the major baby corn producing country. It has great potential both for internal consumption and export.

Uses of Baby corn

Baby corn is a popular vegetable in USA, Europe and Southeast Asia. The demand for baby corn is rapidly increasing in urban areas in India. Baby corn is not a separate type of corn like sweet corn or popcorn and any corn type can be used as baby corn. It is delicacy, which can be profitably used in prolific types of corn i.e. those types, which bear two or more ears per plant. The shank with unpollinated silk is baby corn. The economic product is harvest just after the silks emerge (1-2 cm long). Baby corn has immense potential as a salad and as cooked vegetable. It is used as an ingredient in Chop Suey (Chinese dish), soups, deep fried baby corn with meat, rice and other vegetables. Large number of dishes may be prepared from baby corn as discussed subsequently. Baby corn is highly nutritive. The nutritive value of baby corn is comparable to any common vegetable (Table 1). Since only immature cob is harvested as the economic produce, the crop meant as baby corn can be harvested within 50-55days. Thus in the areas adjoining cities or other urban areas (peri-urban agriculture) multiple crop of baby corn can be raised which would fetch greater income to the farmers. Baby corn can be effectively used as both a nutritious vegetable and as an export crop to earn valuable foreign exchange. After harvest the still young plants may be used as fodder for cattle.

In general, the cultivation practices of baby corn are similar to grain crop except

- (i) Preference for early maturing single cross hybrid with multiple cob bearing ability and regular row arrangement
- (ii) Higher seed rate with (22-25 kg/ha) with high plant population (more than 83,000/ha)
- (iii) Higher dose of nitrogen application (150 to 180 kg/ha)

- (iv) Detasseling just after tassel emergence
- (v) Harvesting unfertilized tender cobs within 1-3 days of silk emergence

Major baby corn in world

It has great potential both for internal consumption as well as for export round the year as 3-4 crops of baby corn can be taken in one year. Thailand is the major baby corn producing and exporting country in the world. India has emerged as one of the potential baby corn producing countries because of the low cost of production as compared to many other countries. Major baby corn producing, exporting and importing countries are mentioned in Table 3.

Table 3. Major baby corn countries

Particulars	Countries
Major baby corn producing countries	Thailand, Taiwan, Guatemala, South Africa, Zambia, Zimbabwe, Peoples Republic of China, Nepal, Japan, Sri Lanka and India
Major baby corn exporting countries	Thailand, Taiwan, Guatemala, S. Africa, Zambia, Zimbabwe and Peoples Republic of China
Major baby corn importing countries	U.S.A., Japan, Hong Kong, Singapore, Australia, Malaysia, Canada, Saudi Arabia, New Zealand, European countries and India

Advantages of baby corn cultivation

1. **Diversification:** The maize is least attractive to the pest as compared to the vegetables. It can be grown round the year and promotes diversification in vegetable cultivated areas where pest and diseases are major problems due to monocropping. Hence, it is suited for peri-urban agriculture diversification.
2. **Intensification:** The crops of bay corn can be harvested earlier than the normal maize crop and 3-4 crops can be taken in a year. It can be grown in the narrow window of two main crop and thus intensified the cropping. In the scenario of the expanding imbalance of land to human resources the baby corn can be a best bet for enhancing productivity and profitability of existing cropping system.
3. **Employment generation:** It provides employment in the form of cultivation, marketing, processing and export. The cultivation of the baby corn is labour intensive.
4. **Earning money in shortest possible time:** Generally farmers have to wait for a longer time for the income from their crops. Being a short duration crop, farmers can earn money in the shortest possible time.
5. **Potential for export:** Baby corn has a great demand in the international market. The foreign exchange can be earned by exporting baby corn and its products.

6. **Quality fodder for livestock:** Green fodder obtained after the harvesting of baby corn can be used as a feed to livestock throughout the year. The farmers can save their land used for green fodder cultivation.
7. **Value addition:** Value addition of baby corn is possible through preparation of several recipes viz, soup, salad, pakora, vegetables, pickles, candy, murabba, jam, laddoo, burfy, etc.
8. **Intercropping:** Intercropping of vegetables, pulses, flowers, etc. can be done with baby corn in *rabi* to ensure additional income to the farmers. The baby corn hybrid (HM-4) based high value (beet root, peas, potato, coriander, fenugreek, radish, cabbage) intercropping systems were evaluated with raised bed planting system at DMR, New Delhi during winter 2007-08 and 2008-09. Results revealed that the baby corn yield under intercropping systems was comparable with sole baby corn. However, the net returns varied significantly under different cropping systems. The increase in profitability of intercropping systems varied from Rs 146900 under baby corn+ pea, Rs 133750 under baby corn + Potato, Rs 125700 under baby corn + coriander, Rs 96500 under baby corn + beetroot, and Rs 79950 under baby corn + radish. The profitability of other systems was either at par or less than sole baby corn systems due to their non compatibility. Other than profitability, there was remarkable advantage on water productivity and employment generation under intercropping systems compared to sole cropping of baby corn or other winter crops.

Production technology of baby corn

In general, the cultivation practices of baby corn are similar to grain crop except some special operation of detasseling and picking of tender cob. However, to achieve higher productivity, following package should be adopted:

1. Selection of suitable varieties:

Being a commercial crop, selection of variety is most important in the baby corn production. The preference should be given for early maturing single cross hybrid with multiple cob bearing ability and regular row arrangement in baby corn production. The hybrids like HM-4, Central Maize VL baby corn 2, VL Baby corn 1, COBC-1 etc. are suitable hybrids for baby corn. The variety should have following characteristics in order to fetch better commercial value in the market. Traits contributing to higher baby corn yield are as follows:

- i) Early maturing single cross hybrids:** To earn better returns in shortest period from baby corn crop, early maturing single cross hybrids are suggested with silking period of 45-50 days in *kharif*, 75--80 days in spring and 120-130 days in winter in North Indian states.
- ii) Medium height and lodging resistance:** Baby corn is cultivated with high plant populations. In general, with high plant density, lodging has been observed. Therefore, hybrid with strong plant type and better root system is preferred.
- iii) Prolific:** Cultivars producing more than one ear per plant are desirable for higher yield of baby corn.

iv) Responsive to high dose of fertilizers: As baby corn is cultivated in higher plant density, fertilizer responsive cultivars are more suitable for the purpose.

v) No barrenness: Varieties possessing no barrenness trait are desirable for proper yield.

vi) Stay green: For getting better fodder quality, genotypes grown for baby corn cultivation must possess the stay green traits. After the picking of baby corn, left over plant material is used as green fodder.

vii) Erect leaves: To accommodate more plant per unit area, erect leaves is a desirable trait. This allows better light interception and hence, enhances net photosynthesis and ultimately increases productivity under high density.

viii) Length of dehusked ear: Preferably not exceeding 10 cm with 1.0–1.5 cm diameter.

ix) Husked to dehusked ratio: It should be 5-6 : 1.

x) Harvesting period: Harvesting period should be within 10- 12 days in kharif / spring and 20 days in winter crop.

xi) Deformity: Each plant should give 3-4 pickings of baby corn. Each baby corn should maintain desirable size and colour.

2. Sowing time: It can be sown round the year except the highly low temperature days during winter season in NEH states. Generally, August to November planting yield best quality baby corn.

3. Sowing method: In case of the big size of the field the sowing should be done in blocks with 7 daytime interval. It will enhance the period of baby con availability and also the efficient utilization of the farm resources. Baby corn should be sowed in the centre of the ridges made at 60 cm apart during monsoon season. Sowing should be done on southern side of the ridges during winter depending upon plant type (erect/spreading). For 60 cm apart ridges plant must be sowed at 10-15 cm row spacing. Furrow sowing should be adopted for baby corn production during summer to enhance the water-use efficiency.

4. Seed rate and plant population: A little higher seed rate than normal maize is required for baby corn production due to more plan population requirement. A seed rate of 22-25 kg/ha is recommended for baby corn production depending on the seed size of the cultivars. An optimum plant population of 83,333 to 1,11,111 is to be maintained for higher and quality baby corn yield by keeping 15 to 20 cm distance between plants after thinning.

5. Seed treatment: Seeds should be treated with fungicides and insecticides before sowing to protect it from seed and soil borne diseases and some insect-pests. The following pesticides should be sued for the respective pests and diseases:

Disease/insect-pest	Fungicide/Pesticide	Application rate (kg ⁻¹ seed)
Seed borne diseases	Bavistin/Captan	2.0 g
Downy mildew	Matalaxyl	2.5 g
Termite and shoot fly	Imidacloprid	6.0 ml

6. Nutrient management: Nutrient application should be based on soil test basis. Generally 120:60:0:25 Kg/ha N,P,K and ZnSO₄ with 8-10 tons/ha FYM should be applied for realizing potential yield of baby corn hybrids. Full dose of phosphorus, potash and zinc and 10 % N should be applied as basal dose. The remaining dose of nitrogen should be applied in four-splits as per details given below to avoid losses and to meet the requirement throughout the crop cycle:

1. 20% N at 4 leaf stage
2. 30% N at 8 leaf stage
3. 25% N before detasseling
4. 15% N after detasseling

If the cobs are not coming up after first/second picking apply 30 kg N/ha for harvesting good yield in subsequent pickings of the baby corn.

7. Weed management: Broad leaf weeds and most of the grasses can be controlled by pre-emergence spray of Atrazine @1.0-1.5 Kg/ ha in 500-600 litre of water. While spraying, the person doing spray should move backward so that the Atrazine film on the soil surface may not be disturbed. Preferably, three nozzle booms may be used for proper ground coverage and saving of time.

One to two hoeings are recommended for aeration and uprooting of the remaining weeds. While doing hoeing, the person should move backward to avoid compaction of soil and to facilitate better aeration.

Herbicides for weed control in traditional tillage Maize are as follows:

Name	Dose (a.i. /ha)	Time of application	Remarks
Atrazine	1000 - 1500 g	Apply with 500 litre/ha of water before emergence of crop as well as weeds	Control all weeds except <i>Dactyloctenium aegyptium</i> (Makra) and <i>Cyprus rotundus</i>
Pendimethalin	1000 ml	Apply with 500 litre/ha of water before the emergence of crop as well as weeds. Suitable for application in intercropping.	Control all weeds except <i>Commelina benghalensis</i> (Cana) and <i>Cyprus rotundus</i>
Atrazine+ Pendimethalin	500 g + 750 ml	Apply tank mix with 500 litre/ha of water before emergence of crop as well as weeds	Control all weeds except <i>Cyprus rotundus</i>
Tembotrione	120 ml	It can be applied as post emergence up to 25-30 days in heavily broadleaf weed infested fields.	It is effective against all weeds.
2,4-D	500 ml	It can be applied as post emergence up to 25-30 days in heavily broadleaf weed infested fields.	It is not effective against sedges and grassy weeds.

8. Water management: First irrigation should be applied very carefully. Water should not overflow on the ridges to avoid the runoff and exposure of the seed for prey to the birds. The irrigation should be applied in furrows up to 2/3rd height of the ridges. 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, silking and picking are the most sensitive stages for water stress for crops and irrigation should be ensured at these stages. Light and frequent irrigations are desirable for crop. During winter (mid-December to mid-February) soil should be kept wet to avoid frost injury in the baby corn.

9. Intercropping: Baby corn is more remunerative, if it is cultivated with intercrop in winter season. As many as 20 crops, namely potato, green pea, rajmash for green pods, palak, cabbage, cauliflower, sugar beet, green onion, garlic, methi, coriander, knol-khol, broccoli, lettuce, turnip, radish, carrot, french bean, celery, gladiolus, etc. have been successfully tried in the winter season (Fig. 1). Since, the season is long therefore, farmers can utilize his lean period and get additional income through intercropping in baby corn. There is no adverse effect of intercrops on baby corn and vice-versa, rather, some of the intercrops help in improving soil fertility and protect the baby corn crop from cold injury. Intercrops protect the baby corn from northern cold wind because baby corn is planted on southern side and intercrops in northern side of the ridge. In general, short duration varieties of intercrops are preferred for intercropping with baby corn. Recommended dose of fertilizers of intercrops should be applied in addition to the recommended dose of fertilizers of baby corn. In *kharif* season, cowpea for green pods and fodder purposes, urdbean, mungbean, etc. can be intercropped with baby corn. Numbers of intercrops are option for the farmers but for commercial purpose, pea and potato can be taken on large scale during winter season.

In the experiment conducted at DMR, the increase in profitability of intercropping systems varied from Rs 1,46,900 under baby corn+ pea, Rs 1,33,750 under baby corn + Potato, Rs 1,25,700 under baby corn + coriander, Rs 96,500 under baby corn + beetroot, and Rs 79,950 under baby corn + radish (DMR, 2010). The profitability of other systems was either at par or less than sole baby corn systems due to their non compatibility. Other than profitability, there was remarkable advantage on water productivity and employment generation under intercropping systems compared to sole cropping of baby corn or other winter crops.



Baby corn + Suagrbeet



Baby corn + Cabbage



Baby corn + Cauliflower



Baby corn + Spinach



Baby corn + Potato



Baby corn + Pea



Baby corn + Carrot



Baby corn + Gladiolus

Figure 1. Suitable intercrops with baby corn in winter season

10. Protection from serious insect pests: Stem borer (*Chilo partellus*), Pink borer (*Sesamia inferens*) and Sorghum shoot fly (*Atherigona* spp) are serious problems in *kharif*, *rabi* and spring seasons, respectively. Stem borer can be controlled by 1-2 spray of Carbaryl after 10 and 20 days of germination. Spraying should be done in the central whorl of plant.

11. Detasseling: To maintain the quality of baby corn, detasseling is an essential operation. It is done by removing the tassel of the plant as soon as it emerges from the flag leaf. It should be practiced row-wise. While detasseling, leaf should not be removed which will otherwise affect net photosynthesis and ultimately reduce average baby corn yield. It has been observed that the removal of 1 to 3 leaves along with tassel reduces 5-15 % yield of baby corn. The removed tassel should not be thrown in the field as it is nutrient rich and should be fed to the cattle.



12. Harvesting: The ears are harvested (45-50 days after emergence) when the silks are 1-2 cm long, i.e., within 1-2 days after silk emergence. Feed corn varieties are harvested at silking, while supersweet varieties may be harvested up to the time silks are about 5 cm long but still fresh. Ears quickly become too long and tough. Suitable time for harvesting of ears may be determined by sampling for size. Harvesting is usually done in the morning when the moisture is high and the temperatures are low. The picking of baby corn is to be done once in three days and generally 7-8 pickings are required depending on genotypes used. Picking should be done daily in *kharif* and on alternate days in winter season within 1-3 days of silk emergence from the leaf sheath depending upon the variety. Harvesting should be done when baby corn silk comes out 2.0-3.0 cm from the top of ears, preferably in the morning or evening, when the baby corn moisture is highest and ambient temperature is low. In single cross hybrid plant, 3-4 pickings may be obtained.



In a good crop on an average 15-19 q/ha baby corn can be harvested. Additional income may also be obtained through sale of green fodder, which may yield up to 250-400 q/ha. The husk is to be carefully removed so as not to break or damage the ear. Ears intended for processing must be carefully hand husked and de-silked. Subsequent to the removal of the ear husks, the shanks are cleared of the silks. Then the shanks are graded based on their size and colour and packed in polythene sheets before marketing. In many cases baby corn for vegetable use is marketed without dehusking of the cobs. This reduces labour involved in processing but fetches less market price. Optimum size for market and cannery industries is 4.5-10 cm long and 7-17 mm diameter of dehusked cobs. Yellow coloured cobs with regular row arrangement fetch better market price. Harvested baby corn may be stored for 3-4 days at 10 °C 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. Baby corn

pickle is also gaining popularity in Indian market and it already has an established international market, particularly in Europe.

13. Yield: It depends on potential of genotypes and climatic conditions. In a good crop, on an average 55-114 q/ha husked baby corn or 11-19 q/ha dehusked baby corn can be harvested. Green fodder yield is about 150-400 q/ha that gives additional income to the growers.

The effort should be made to peel the baby corn on the same day and stored in a cool and dry place. It should be carried out in shady places having good ventilation and air circulation. De-husked baby corn should be put in containers like plastic baskets, bags, sacks and ensure that they are not heaped. Baby corn should be transported to the processing unit at the earliest. Following are the quality traits of baby corn need to be considered for higher market price:

- Baby corn should be uniform in color, shape and size.
- Color of baby corn should be creamish or light yellow.
- Ears should be straight.
- Ears should not have slitting marks
- Ears should be fresh, free from defects like rotting, over dryness, over ripening and water soaking. Trimming of baby corn should be neat and leave no scars on ears.
- Ovule/row arrangement should be regular and straight.



14. By-products: Following by-products obtained by the baby corn production:

1. Tassels
2. Silks
3. Husks
4. Green plant material after harvest

All these by-products are highly nutritive and can be fed to the cattle which increase milk yield.

Significance of sweet corn

Sweet corn

Sweet corn is one of the most popular vegetables in the USA, Europe and other developed countries of the world. It is a very delicious and rich source of energy, vitamin C and A. It is eaten as raw, boiled or steamed green cobs/ grain. It is also used in preparation of soup, salad and

other recipes. It is becoming very popular in urban areas of country therefore, its cultivation is remunerative for peri-urban farmers. Besides green cobs the green fodder is also available to the farmers for their cattle. Generally sweet corn is early in maturity. It is harvested in 70-75 days during kharif season. Green cobs are harvested after 18-20 days of pollination during kharif but the duration may varies season to season. At the harvest time the moisture is generally 70 % in the grain and sugar content varies from 11 to more than 20 %.

- A delicious and rich source of energy, vitamin C and A used in preparation of soup, salad and other recipes
- Varieties: HSC1 for J&K and HP & Madhuri, Win orange, Priya for other states
- Seed rate: 8 kg/ha
- Spacing: 75cm X 25-30 cm
- Green cobs are harvested after 18-20 days of pollination during kharif
- Picking should be done in evening
- Generally sweet corn is early in maturity & harvested in 70-75 days during kharif
- At the harvest time the moisture is generally 70 % in the grain and sugar content varies from 11 to more than 20 %

Color: Sweet corn is generally dull yellow and white but dull yellow color is preferred.

Precaution: Its picking should be done in the morning or evening time. Green cobs should be immediately transported to the cold storage in refrigerated trucks to avoid the conversion of sugar to starch. It loses flavor if kept in high temperature after picking.

Sweet corn with high sugar content should not be planted when temperature is below 16°C.

Package of practices in Sweet corn cultivation in NEH region

Choice of cultivar:

Maturity group/type

Hybrids/cultivar

Sweet corn

Hybrids: Hi Brix 53, Hi Brix 39, Cnetral Maize VL Sweet corn
1, Candy, Mishti
Composites: Priya, Madhuri, Win orange

Time of sowing: Optimum temperature for maize growth and development is 18 to 32 °C, with temperatures of 35 °C and above considered inhibitory. The sowing of sweet corn could be avoided before 40-50 days before expected heavy rainfall period or temperature more than 30 °C.

Seed treatment

Disease/insect-pest	Fungicide/Pesticide	Application rate per kg seed
Seed borne diseases (TLB, MLB, CLS)	Bavistin/Captan	2.0 g
Downy mildew	Matalaxyl	2.5 g
Termite and shoot fly	Imidachlorpid	3.0-4.0 ml

Seed rate and plant population:

Type/purpose	Seed rate (kg ha ⁻¹)	Plant geometry (plant x row, cm)	Plant population per ha
Sweet corn	8	75 x 25; 75 x 30	44444 to 53333

Nutrient management:

- Seeds treatment with three packets of *Azospirillum*
- Application of 10-15 t ha⁻¹ FYM
- 120 kg N, 60 kg P₂O₅ ha⁻¹ for hybrid sweet corn.
- Apply 1/3 rd of N each at basal, knee high and tasseling stage; splitting of potassium is also found beneficial
- Or apply 25% N as basal and rest 75% N in four splits as top dressing as follows:

S. No.	Crop Stage	Nitrogen rate (%)
1	V ₄ (four leaf stage)	25
2	V ₈ (eight leaf stage)	30
3	V _T (tasseling stage)	20

- *Azotobacter/Azospirillum* + *Phosphobacteria* 2 kg each/ha along with FYM application in case of no seed treatment with biofertilizer.

Weed management: please follow as written for the baby corn earlier.

Insect management:

- For *Chilo* and *Sesamia* control, foliar spray of Carbaryl @ 2.5 g/litre at 10 days after germination.
- The *Chilo* can be controlled by release of 8 Trichocards per ha at 10 days after germination.
- **Intercropping of maize with cowpea** is an eco-friendly option for *Chilo* control.

Disease management:

TLB, MLB: Need based sprays of Mancozeb @ 2.5 g/l.

BLSB: Stripping of lower 2-3 leaves along with their sheath & tolcofos-methyl @ 1g/ l or Validamycin @ 2.7ml/l

Downy mildew: Metalaxyl @ 2-2.5g/l is recommended at first appearance

Harvesting:

20 days after pollination (Green cobs: 40-50 q/acre & green fodder: 120-150 q/acre)

Opportunities for the specialty corn in NEH states:

- 1. Availability of the soil and water:** The north eastern regions hosts the soil having high organic matter which is very much suitable for the low input requiring baby corn crop and for even sweet corn as well. The water is also of good quality and available in the NEH region and with expansion of the electricity. The villages of the baby corn and sweet corn may be established in all the NEH states to cater the domestic needs and for export to the Japan and other countries.
- 2. Sufficient work force:** The country is facing shortage of the employment generation and especially in NEH region due to less industrialization. In this scenario, the traditional agriculture sector could be revived by interdiction of the high value crops like baby corn and sweet corn for employment generation. This will also help in checking the migration of the rural youth and will improve the livelihood security of the farmers.
- 3. Tourism promotion:** In recent past and with future project of road linkage by government of India, the unexplored NEH region of the country is going to tourist hub in the country due to attraction of scenic natural butties. In the tourist areas, the cultivation and sale of the raw and processed baby corn and sweet corn product like baby corn *pakora*, baby corn mixed vegetable and salad, steamed sweet cob and sweet corn soup will have great promise for generation of the income to the farmers.
- 4. Value addition and processing industries:** Due to good availability of water sources in the flood plains of the Brahmaputra River and the energy, availability provides enough opportunity for the establishment of the baby corn and sweet corn processing plants. These plants also require very less energy and can be run on biomass energy as well.
- 5. Employment generation:** There is great opportunity to engage more people in the baby corn cultivation and processing as this is the labour intensive and provides employment to all stage people, youth and women.

6. **Livestock promotion:** The green fodder and the cob sheath generated by the cultivation of baby corn and sweet corn is very nutritious. This could help in the bridging the gap for fodder requirements of the livestock and hence will help in improving productivity of this sector as well.
7. **Organic specialty corn:** The importer of the baby corn and sweet corn are the high-income economies of Northern America, Japan and Europe. The NEH soils are in general rich in the organic matter as well as there is not much requirement of nutrients in baby corn as there is no need to go for the seed. Hence, this crop could be an important candidate for the organic cultivation. These can be exported for the earning of forex and will also increase employment and livelihood security of the farmers in the NEH region.
8. **Technology available:** There is enough technological intervention available for specialty corn in NEH states. The cultivars of the baby corn like HM-4, VL Baby corn 1, etc and in sweet corn Hi Brix 53, Hi Brix 39, Central Maize VL Sweet corn 1, Candy, Mishti, etc. The production and processing technologies also developed and adopted in Atterana and adjoin villages of Sonipat for baby corn and Manauli areas of Sonipatin Haryana for sweet corn.

Challenges for specialty corn in NEH states:

1. **Establishment of the market linkages:** Being a difficult terrain and the less connection of hinterlands of NEH region warrants the establishment of the seed to marketed product linkages in the value chain. Further, these personnel in entire value chain must/will be from the NEH regions and thus requires intensive trainings on the various aspects of the specialty maize production. These trainings could be the part of the RKVY projects and NHM projects of this region. Establishments of the seed hubs, baby corn and sweet corn processing and processing plants will add up towards making success of the specialty maize cultivars in NEH regions.,
2. **Training to the producers:** The cultivation of these specialty types of the maize is not penetrated in NEH region and hence the farmers are mostly friendly with traditional maize growing of the
3. **Trainings to the trainers:** As the baby corn and sweet corn are the specialty type of maize and hence if produced with the normal maize practices could not be remunerative. Hence, intensive class room and on farm trainings of the state government officials and other trainers of the ICAR is need for the proper dissemination of the knowledge about these specialty maize types.
4. **Assured seed supply at affordable prices:** The government of the states can help by establishing the seed villages under the RKVY scheme. The current price of the available seed of the baby corn is Rs 350 to 550 while for sweet corn it is much higher up to Rs 2250 to 2500 per kg.

5. Transportation: The baby corn and sweet corn being a perishable commodity needs a transport network that is faster to fetch the appropriate prices in the market. In NEH region of difficult terrain this is relatively slow and hence will be a challenge for its wider adaptability amongst the hinterland farmers. However, the areas near cities could go for it easily. For hinterland, the air-conditioned transport system or the processing industries establishment could be a solution where villages of the baby corn and sweet corn could be established like a business module.

Products of Baby Corn



Baby corn Burfi



Baby corn candy



Baby corn chat



Baby corn Chilli



Baby corn Chutney



Baby corn Cutlet



Baby corn Halwa



Baby corn Jam



Baby corn Murraba



Baby corn Pakora



Baby corn pickle



Baby corn Kofta curry

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QUALITY PROTEIN MAIZE: OPPORTUNITIES AND CHALLENGES IN NEH REGION

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Maize (*Zea mays* L.) is the third most important crop, after rice and wheat, globally that is cultivated in diverse ecologies ranging from tropics, sub-tropics and temperate regions up to 50° N and S from the equator to more than 3000 m above sea level under irrigated to semi-arid conditions. Maize is the crop with high productivity and enormous diversity and therefore considered future crop for tackling emerging challenges. In India, maize is an important cereal grown on an area of 9.2 million hectares with production of 24.2 million tons (www.indiastat.com) and contributes ~ 9 per cent to the food basket despite being cultivated as rainfed crop in 80 per cent of its area (2012-13). In north-eastern part of India maize is mainly cultivated in Sikkim, Arunachal Pradesh, Tripura, Manipur and Assam. Sikkim is the leading state in terms of area, production and productivity contributing more than 25% to total maize production in North-Eastern India (Figure 1). Majority of maize produced in India is consumed in poultry, fish, piggery and other livestock (63%), 21% is used directly as food and nearly 12% in milling and brewery industry.

Maize grains are nutritionally rich in carbohydrates, fats, proteins and some of the important vitamins and minerals. Maize contains an average of 14.9% moisture, 11.1% protein, 3.6% fat, 2.7% fibre, 66.2% other carbohydrates and 1.5% minerals. Maize kernel protein is made up of five different fractions, viz. albumin (7%), globulin (5%), non-protein nitrogen (6%), prolamine (60%) and glutelin (25%). Maize is called nutri-cereal because it fulfils nutrition and calorie requirement of large masses in developing countries. However, the large amount of Zein fraction in maize protein confers poor net protein utilization to normal maize genotypes owing to deficient in essential amino acids viz. lysine and tryptophan. Hence, the need was felt to overcome this problem of poor nutritional value in conventional maize genotypes.

QPM History and importance

The scientist found a new hope in 1920 with the identification of a natural mutant called as *opaque 2* by Singleton that was characterized by soft and opaque grains (Singleton, 1939). The recessive homozygous version of *o-2* mutants were found to possess double the amount of lysine and tryptophan as compared to existing normal maize cultivars. The discovery of *o-2* mutants provided a boost to the researchers to explore the area related to genetic manipulation of protein quality in maize resulting in discovery of several amino acid composition altering mutants. However, *opaque 2* gene remained target gene for amino acid composition alteration for a long run marked by its introgression into various varieties and inbred lines through

conventional breeding. All India Coordinated Research Project on Maize led research resulted into development and release of three *opaque-2* OPVs but the beneficial effects of *o2* mutation for higher lysine and tryptophan were masked by its association to deleterious pleiotropic effects viz. soft chalky endosperm, reduced dry matter accumulation and thus decreased grain yield, dull soft chalky kernel phenotype with greater susceptibility to ear rots and stored-grain pests and slower field drying following physiological maturity. The strategy to overcome these deficiencies initiated under the leadership of Dr. S.K. Vasal and his team at CIMMYT and identified various endosperm modifier genes that could favorably alter the grain characteristics, thus resulting into development of Quality Protein Maize (genotypes possessing *opaque 2* gene with hard endosperm *He* gene conferring kernel vitreousness, genetic modifiers). This discovery resulted into success of cultivars that have high tryptophan (>0.6%), high lysine (>2.4%), balanced leu to isoleucine ratio, lower zeins, with corresponding increase in non-zein fraction in endosperm proteins (Table1). Average lysine and tryptophan concentration in *o2* maize is about double as compared to normal maize (Vivek *et al.*, 2008). The favorable leucine-isoleucine ratio results in reducing pellagra due to liberation of more tryptophan for niacin biosynthesis (Vasal 2001). The balanced proportion of all this essential amino acid in QPM resulted in enhanced biological value of protein. Although the true protein digestibility of QPM matches with maize, but the biological value of QPM is twice that of normal maize. The appearance and taste of QPM is similar to normal maize but with balanced amino acid profile. The progress in breeding of superior QPM cultivars has shown a hope for the strengthening of nutritional security for the economically deprived sections of the society. In India various centres of AICRP maize have put extensive efforts to develop and release many QPM cultivars that cover a good amount of area of cultivation. With the advent of molecular markers, first marker-assisted selection based QPM hybrid, 'Vivek QPM 9', was released by ICAR-Vivekananda Parvatiya Krishi Anusandhan Sansthan, Almora in 2008 (Gupta *et al.*, 2013) followed by Vivek QPM-21 released in 2012. QPM version of five commercial hybrids, viz., HM-4, HM-8, HM-9, HM-10, and HM-11 have also been developed by extensive efforts at ICAR- Indian Agricultural Research Institute, New Delhi (Hossain *et al.*, 2014). The list of released hybrids along with their characteristics has been provided in Table 2 and 3.

Opportunities of QPM in NEH region

1. Nutritional package: QPM is considered a poor man's cereal owing to its nutritional benefits. QPM cultivars provide a biofortified grain with improved protein quality or nutrition to various consumers ranging from infants to lactating mothers. The green cob of QPM is nutritious, liked by people of most ages, and thereby provides a great opportunity of easily replacing the normal maize with QPM. It provides a cost effective and sustainable solution to alleviate malnutrition in remote areas. In the present scenario of greater inflation the poor mass of India cannot afford the protein rich source such as egg, fruits, vegetables and milk products, thereby QPM provides

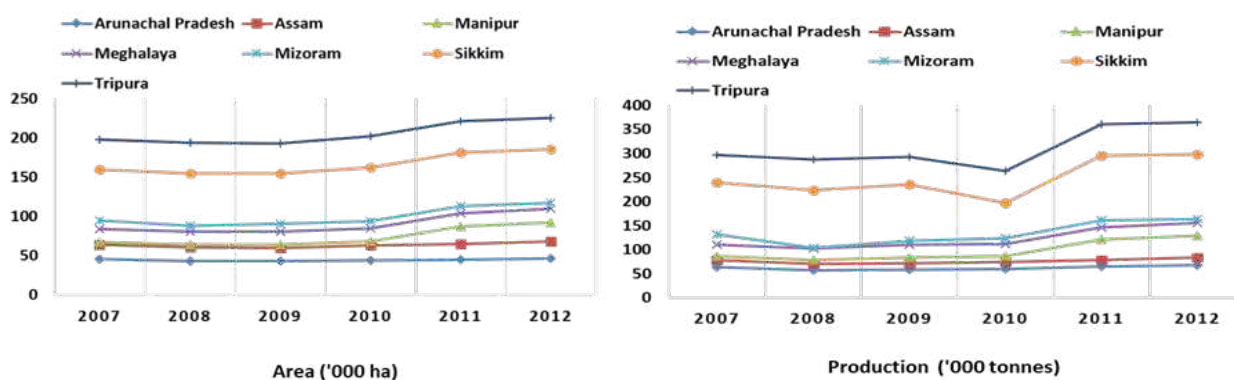
affordable option to the economically deprived section to meet their nutritional requirements. The various value added products maize using QPM found beneficial for growing children, lactating mothers, adolescents, old aged persons and women who are the nutritionally deficient in the India. The recipes of these value added QPM products (>35) is available on <http://agridaksh.iasri.res.in/maize.jsp>.

2. Processing Industries: Protein fractions in QPM are robust to many traditional processing and cooking techniques. High biological value of QPM will reduce food/feed cost and its efficacy can be cited from areas where replacement of normal maize by QPM as feed have resulted into tremendous positive results in health of broilers, chickens and pigs. QPM fed beef steers have been found to gain weight faster than fed on normal maize. The QPM based nutritious processing products can replace fancied and highly priced industrial foods. The QPM processing based entrepreneurship can gain high success as cited from the *Cornitos* product available in market and there is continuous demand for the QPM seed for interrupted supply of such products.

3. Entrepreneurship support: Indian government is steadily improving the financial support to initiate new start-ups. There is increasing demand of pre-packaged foods owing to high rate of urbanization. The QPM can be processed to make various pre-packed foods such as QPM laddoo, kheer etc. thus providing greater avenues of employment to young entrepreneurs and thus strengthening the Indian economy.

4. Good quality silage: There is a big demand for continuous supply of the fodder all around the India. The studies report about the better quality of silage prepared from QPM as compared to that from normal maize. The silage prepared from QPM can be processed into block form or pellet form for easy transportation and can prove to be a good source for entrepreneurship development.

5. Adequate nutritious animal feed: The demand for the animal-based products such as eggs and meat are increasing with the changing food habits of younger generation. More than 50% of the maize production is utilized for the animal feed such as poultry and piggery. NEH region are suitable place for fetching greater income through backyard poultry and piggery. The eggs produced from QPM fed poultry are found to be nutritionally superior. The research on enriching QPM with Provitamin A will further increase the nutrient status of the egg that is important component of mid-day meal programme and thereby improving the nutritional status of children.



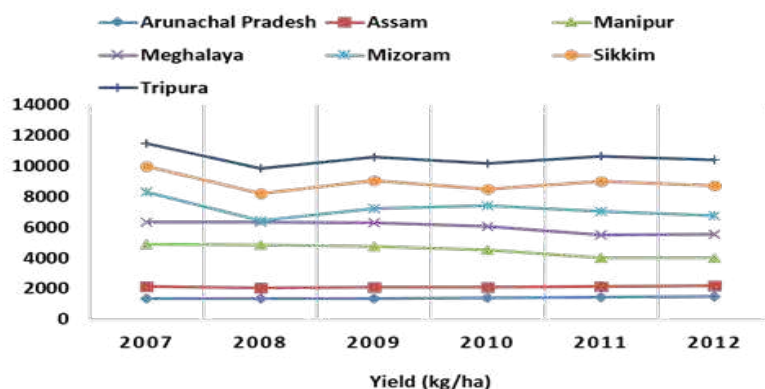


Figure 1. Area Production and Productivity of Maize in North Eastern States of India

Table 1. Biochemical parameters of QPM *vis-a-vis* normal maize

Biochemical Parameter	Normal corn	QPM	Biochemical parameter	Normal corn	QPM
Tryptophan	0.3 or less	0.6 or more	Glutelin	35.1	50.0
Lysine	1.2-1.5	2.4 and above	Isoluecine	2.06	1.93
Albumins	3.2	13.2	Leucine	8.27	5.07
Globulins	1.5	3.9	True protein digestibility	82	92
Prolamine	47.2	22.8	Biological value	42	80

Table 2. QPM Hybrids developed and released for NEH India.

Hybrid	Year of release	Pedigree	AICRP(M) Centre	Characteristics
HQPM-4	2010	HKI-193-2 X HKI-161	CCS HAU, Karnal	Late maturity, yellow, semi-flint, , avg. yield 60q/ha
HQPM -7	2008	HKI-193-1 X HKI-161	CCS HAU, Karnal	Late maturity, yellow, semi-flint, avg. yield 72q/ha
Vivek QPM 9	2008	VQL 1 X VQL 2	VPKAS, Almora	Extra- early maturity, yellow, dent, avg. yield 55 q/ha
HQPM 5	2007	HKI 163 X HKI 161	CCS HAU, Karnal	Late maturity, orange, flint, avg. yield 58 q/ha
HQPM 1	2007	HKI 193-1 X HKI 163	CCS HAU, Karnal	Late maturity, yellow, dent, avg. yield 62 q/ha

Table 3.Protein and tryptophan content in QPM hybrids

Hybrid	Protein content (%)	Tryptophan content in protein (%)	Hybrid	Protein content (%)	Tryptophan content in protein (%)
HQPM 1	10.09	0.79	VQPM -9	9.2	0.70
HPQM 4	10.30	0.67	Shaktiman-1	10.62	0.70
HPQM 5	10.15	0.69	Shaktiman-2	10.29	0.72
HQPM-7	9.8	0.72	Shaktiman-3	9.27	0.70

Challenges in QPM adoption

1. Poor Adoption Rate: The general apprehension of low yield potential of QPM genotypes among farmers hinders the dissemination of its adoption. This problem can be addressed by the combined approach of development of high yielding QPM varieties followed by wide demonstration of their good yield potential. The successful example can be cited from wide adoption of Vivek QPM-9 having similar grain yield potential as that of the original hybrid, VivekHybrid-9 (Gupta et al. 2013). Considering the limited diversity in QPM inbred lines there is need to strengthen the QPM breeding programmes by developing diverse heterotic pools followed by elite QPM line derivation.

2. Lack of Isolation distance: The biggest challenge of QPM breeding lies in the fact that the trait is governed by recessive genes and hence vulnerable to xenia effect. This necessitates the maintenance of isolation distance in QPM field to avoid the contamination of grain quality from normal maize pollen. The contaminated harvest is nutritionally inferior to original QPM produce and thereby fetching lower price. Most of the farmers in India are marginal and hence unable to provide isolation distance. This problem can be tackled by the successful implementation of production village concept like Manoli village for sweet corn where the entire village is adopted to cultivate sweet corn and nearby Atterna village producing baby corn at large scale.

3. Lack of awareness on QPM derived health benefits: The reports suggest the coverage of only 1% area under QPM of total cultivable area of maize in Mexico, Latin America, Sub-Saharan Africa and Asia (CIMMYT, 2012). This indicates the lack of awareness among the people regarding nutritional value of QPM. Indian mass also need to be updated about the QPM derived health benefits through extensive extension and sensitization activities.

4. Less organized processing- and value-addition-industries: The adoption of QPM based products is expected to gain momentum on establishment of more organized food processing and value addition industries. The successful example of processed products can be cited from RAU which has released various QPM based food products such as ‘Pusa-Shakti’, ‘Kheer-

mix/Dilkhush' Kadhi mix/Proteino-H' (Singh and Chandra, 2014). Empowerment of women can also be done in NEH region through promotion of QPM-based food processing and value-addition industries producing flakes, chips, biscuits, etc. that is already in progress in India. Though the industry is ready to buy the QPM, the availability of the rapid/quick methods for QPM identification differentiating normal maize is lacking. Hence, the processor found it difficult to buy QPM and provide premium pricing.

5. Inadequate policy support: Contradictorily to basmati rice, QPM having higher nutritional value could not attract the policy support and hence having less adoption among the farmers. Policy support through subsidized seeds and other inputs, better minimum support price, easy loan to village-level entrepreneurs for setting processing based enterprises would help to boost the adoption of QPM in India.

6. Lack of regional hubs for Seed production: QPM hybrid seed availability is an issue that hampers the spread of acreage of QPM. There is need to identify the specific regional hubs with requisite isolation distance, good connectivity of roads, assured irrigation and storage facilities can help to assure the regular supply of quality seed. The NEH region in *rabi* season offers a great opportunity to take up seed production to make available the cheaper seed for timely sowing. The research on QPM breeding has remained mostly in the hands of public sector that can excel to greater heights if provided support of state policy.

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HYBRIDS TECHNOLOGY FOR DOUBLING MAIZE PRODUCTIVITY

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Maize Scenario

Maize (*Zea mays* L.) is the most versatile food crop being grown on 188 million ha area in more than 170 countries across the globe with 1060 million ton of production and 5.6 tonnes/ha productivity (FAOSTAT, 2018). In India, the maize area has reached to around 9.6 million ha with production and productivity of 26.88 million tones and 2.8 t/ha, respectively (3rd advance estimate of 2017-18: <https://eands.dacnet.nic.in>). It can be grown around the years in one or another part of the country with elevation ranging from sea level to up to 3000 m amsl.

Maize is also known as queen of cereal as it has highest yield potential amongst the major cereal crops. The consumption pattern of maize (feed-64%, food-16%, industry-19%, seed and other miscellaneous 1%) in India largely matches with the global pattern (feed-61%, food-17% and industry-22%). Further, it is an important industrial raw material where more than 3000 products are being made from it providing wide opportunity for value addition.

The USA and China together contributes about more than 38% of area and 58% of the production of the world's maize. Major factors favouring for better performance of USA and China primarily includes adoption of single cross hybrids/ plus transgenic technology with long crop duration, assured irrigation and high inputs in maize production. In India, ~80% of maize is grown as rainfed crop and provides low cost nutritious and risk free green fodder to the livestock. Adoption of single cross hybrid technology by replacing the composites, multiple parent crosses and synthetics cultivars after 2000 onward paved the way to enhanced maize production and productivity in India. The SCHs of maize may have the yield potential of more than 12.0 t/ha, which is significantly very higher from composites and synthetic cultivars. Apart from normal maize, it has many other types' viz. Quality Protein Maize (QPM), sweet corn (SC), baby corn (BC), pop corn (PC), waxy corn (WC), high oil (HO) etc. The cultivation of maize as baby corn, popcorn and sweet corn has increased the income of the farmers many fold, which has given livelihood security to *peri*-urban farmers thus checking the rural urban migration.

Ecologies for maize cultivation in India

Based on the agro-ecological conditions, the entire India has been divided in five major zones –Northern Hill Zone (Zone I), North West Plains Zone (Zone II), North East Plains Zone (Zone III), Peninsular Zone (Zone IV) and Central Western Zone (Zone V) for effective

evaluation and identification of suitable hybrids as well as breeding materials of maize. The details of maize growing states included in these zones are given in Table 1.

Table 1. Different zones for maize cultivation in India

Zone	States
Northern Hill Zone (NHZ), Zone-I	Jammu and Kashmir, Himachal Pradesh, Uttarakhand (Hill region), North Eastern Hill Regions (Meghalaya, Sikkim, Assam, Tripura, Nagaland, Manipur, Arunachal Pradesh
North West Plains Zone (NWPZ), Zone-II	Punjab, Haryana, Delhi, Uttarakhand (Plain), Uttar Pradesh (Western UP)
North East Plains Zone (NEPZ), Zone-III	Bihar, Jharkhand, Odisha, Uttar Pradesh (Eastern UP), West Bengal
Peninsular Zone (PZ), Zone-IV	Maharashtra, Karnataka, Andhra Pradesh, Telangana State, Tamil Nadu
Central Western Zone (CWZ), Zone-V	Rajasthan, Madhya Pradesh, Chhattisgarh, Gujarat

Hybrids priority for different regions

In low to medium average rainfall sub-region viz., central part, part of northern India and western region of the country, moisture stress is the key constraint to maize production. Therefore aggressive breeding efforts to overcome the drought problem are needed thought to be more relevant for this region. Development of early and medium maturity hybrids can be the one of important component of breeding strategies for these regions. For more favorable production environments, breeding efforts needs mostly for development of full as well as medium maturity maize hybrids having tolerance to biotic stresses viz. Stem borer, turcicum leaf blight and post flowering stalk rot. Now winter maize is coming in a big way, therefore, long duration maize hybrids, tolerant to cold are more useful. In spring season early and medium duration hybrids, which need to be heat stress tolerant are more preferable compare to late maturity. The objectives of single cross hybrids development are therefore based on the zonal and season requirements. Generally, Northern Hill Zone (Z-I) requires early and medium duration drought tolerant hybrids, North West Plains Zone (Z-II) requires early, medium and late duration drought tolerant during *kharif*, heat tolerant in spring and cold tolerant single cross hybrids during *rabi* season. The North East Plains Zone (Z-III) requires water logging tolerant cultivars in *kharif* and long

duration cold tolerant hybrids in *rabi* season, in Peninsular Zone (Z-IV), depending upon the cropping pattern, all type of maturity groups can be grown with more preference to long duration where the irrigation facility is available. In Central Western Zone (Z-V), early to medium duration drought tolerant during *kharif* and late cold tolerant hybrids during *rabi* season are more preferable for cultivation.

Maize hybrids technology

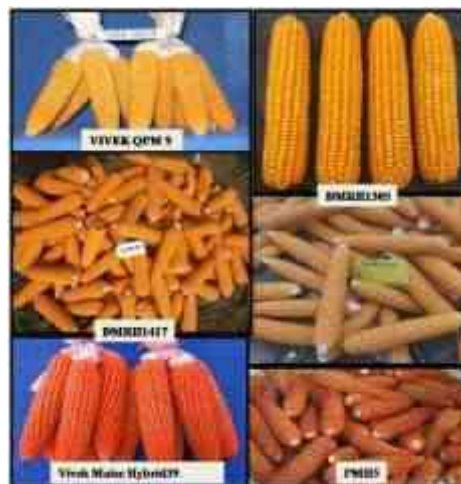
One of the major achievements in maize breeding has been the exploitation of heterosis through commercial cultivation of maize hybrids. Inbred found better combiner is crossed in specific combination to develop hybrids. Inbred development in maize hybrids breeding is one of the most important components. A pure inbred line is a homozygous and homogeneous population developed by continuous inbreeding, usually by self-pollination, followed by selection during subsequent segregating generations. Complete self-cob of the selected plant should be grown in long row of length 25 to 30 m in field for effective and efficient selection during the segregating generations. Preference should be given to select more progenies of a cross having less inbreeding depression than that of selecting more crosses carrying progenies having high inbreeding depression. The fixed selected inbred lines (selfed for 6-7 generation) are crossed in specific combination represents the types of hybrids. There are different types of hybrids viz., single cross ($I_1 \times I_2$, I denoting an inbred), modified single cross [$(I_1 \times I'_1) \times I_2$, I' denoting the sister lines], three way cross [$(I_1 \times I_2) \times I_3$], modified three way cross [$(I_1 \times I_2) \times (I_3 \times I'_3)$] and double cross [$(I_1 \times I_2) \times (I_3 \times I_4)$]. A cross between two varieties is a varietal hybrid and between variety and an inbred line is a top cross hybrid. Among all types of hybrids, the single cross hybrids, which are more uniform, productive and tolerant to major biotic and abiotic stresses, easy to maintain purity and multiply seed are mostly recommended for commercial cultivation.

Advantages of single cross hybrids technology

Area, production and productivity remain stagnant for many years in India due to the cultivation of less productive OPVs and multi parent hybrids. The impact of single cross hybrids (SCHs) technology adoption has already been witnessed in USA, China and many other countries of world. Even in India by hardly covering 25-30% area under single cross hybrids, the crop growth rate with respect to area, production and productivity of maize has increased significantly. The total maize produced during 1950-51 in India was around 1.73 mt, which has increased to 25.90 mt by 2016-17 (15 times higher than the base).

Details advantages of SCHs technology are given below:

1. Uniform, high yield potential & farmers acceptable
2. Tolerant to biotic and abiotic stresses
3. Wider adaptability in the era of climate change
4. Quick and higher germination %
5. Fair dealing to all farmers, industries, dealer etc
6. Employment generation
7. Provide food, feed and nutritional security
8. Export potential & foreign exchange



Specialty Corn – for Livelihood Security

With the increase of urbanization, change in food habit and economic status, the specialty corn has gained significant importance in *peri*-urban areas of the country. The demand of baby corn, sweet corn and popcorn is increasing every year. To check the migration from rural to urban, to enhancing the profitability and livelihood security of the farmers, the suitable hybrids and production technology for baby corn and sweet corn have been developed. The farmers can earn 50-60 thousand rupees per annum per acre with the cultivation of 2-3 crops of baby corn and sweet corn. Besides, they can harvest green and nutritious fodder for livestock. Specialty corn cultivation may provide livelihood security to the farmers through following ways:

- Employment generation
- Check the migration of peoples from rural to urban
- Solve the green fodder scarcity
- Promote livestock industry
- Increase the milk production by availing green fodder
- QPM maize for nutritional security

Table 2. Details of public sector single cross hybrids of maize identified/released for cultivation in northern hill zone (NHZ) since 2000.

S. No.	Cultivar	Organization/Center	Year of identification /release	Duration	Area of adaptation	Average Yield (t/ha)	Cropping season
1	DMRH1305	ICAR-IIMR, Ludhiana	2018	Early	J&K, HP, Uttarakhand (Hills) & NEH states	6.5	Kharif
2	Pusa Vivek QPM-9 (APQH9)	ICAR-IARI, New Delhi	2017	Ex. Early	J&K, HP, Uttarakhand (Hills) & NEH states, Maharashtra, Karnataka, AP, Telengana & TN	5.9	Kharif
3	Vivek Hybrid 27 (Central Maize VL Baby Corn 2)	ICAR-VPKAS Almora	2017	Early	Jammu & Kashmir, Himachal Pradesh, Uttarakhand, Punjab, Haryana, Delhi, UP, Maharashtra, Karnataka, Tamil Nadu, Telangana, Andhra Pradesh, Gujarat, Rajasthan, Chhatisgarh and Madhya Pradesh	2.0	Kharif
4	Central Maize VL 55 (FH3605)	ICAR-VPKAS Almora	2017	Medium	Jammu & Kashmir, Himachal Pradesh, Uttarakhand, NE Hills, Maharashtra, Karnataka, Tamil Nadu, Telangana and Andhra Pradesh	6.5	Kharif
5	Central Maize VL Sweet corn 1 (FSCI18)	ICAR-VPKAS Almora	2016	Medium	Jammu & Kashmir, Himachal Pradesh, Uttarakhand, NE Hills, Punjab, Haryana, Delhi, Western UP, Karnataka, Tamil Nadu, Telangana, Andhra Pradesh, Gujarat, Rajasthan, Chhatisgarh and Madhya Pradesh	11.0	Kharif
6	HM-13 (HKH-317)	CCSHAU, Hissar	2015	Early	Jammu and Kashmir, Himachal Pradesh and Uttarakhand	6.6	Kharif
7	Vivek Maize Hybrid 47 (FH 3513)	ICAR-VPKAS Almora	2014	Early	Uttarakhand, Himachal Pradesh, Jammu & Kashmir, Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Tripura and Sikkim	6.9	Kharif
8	Vivek Maize Hybrid 53 (FH 3556)	ICAR-VPKAS Almora	2014	Extra-early	Uttarakhand, Himachal Pradesh, Jammu & Kashmir, Uttar Pradesh, Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Tripura and Sikkim	6.9	Kharif

S. No.	Cultivar	Organization/ Center	Year of identification /release	Duration	Area of adaptation	Average Yield (t/ha)	Cropping season
9	Pant Shankar Makka-1	GBPUA&T, Pantnagar	2013	Early	Uttarakhand	4.8	Kharif
10	Vivek Maize Hybrid 45 (FH 3483)	ICAR-VPKAS Almora	2013	Extra-early	Uttarakhand, Himachal Pradesh and Jammu & Kashmir	5.4	Kharif
11	Vivek Maize Hybrid 39 (FH 3356)	ICAR-VPKAS Almora	2012	Extra-early	Uttarakhand and Himachal Pradesh	5.8	Kharif
12	HSC 1 (Sweet Corn)	CCSHAU, Hissar	2010	Medium	Himachal Pradesh and Uttarakhand	12	Kharif
13	Vivek Maize Hybrid 33 (FH 3352)	ICAR-VPKAS Almora	2008	Extra-early	Himachal Pradesh, Jammu & Kashmir and Uttarakhand	6.0	Kharif
14	Vivek QPM 9 (FQH 4567)	ICAR-VPKAS Almora	2008	Extra-early	Jammu & Kashmir, Uttarakhand, Himachal Pradesh, Andhra Pradesh, Tamil Nadu, Karnataka and Maharashtra	5.0	Kharif
15	Vivek Maize Hybrid-25 (FH 3248)	ICAR-VPKAS Almora	2007	Extra-early	Uttarakhand, Himachal Pradesh, Jammu & Kashmir and NEH	5.3	Kharif
16	HQPM-5	CCSHAU, Hissar	2007	Late	Across the country	5.8	Kharif
17	HQPM-1	CCSHAU, Hissar	2007	Late	Across the country	7.5	Kharif
18	Vivek Maize Hybrid-21 (FH-3211)	ICAR-VPKAS Almora	2007	Extra-Early	Uttaranchal and Himachal Pradesh	4.8	Kharif
19	Vivek Maize Hybrid-23 (FH-3529)	ICAR-VPKAS Almora	2007	Early	Hills of Uttarakhand	4.8	Kharif
20	HM-4	ICAR-VPKAS Almora	2005	Medium	Across the country	8.4	Kharif
21	Vivek Maize Hybrid-15 (FH-3176)	ICAR-VPKAS Almora	2005	Extra-early	Jammu & Kashmir, Uttarakhand, Himachal Pradesh	7.3	Kharif
22	Vivek Maize Hybrid-9 (FH 3077)	ICAR-VPKAS Almora	2001	Extra-early	Himalayan regions, Andhra Pradesh, Karnataka and Tamil Nadu	4.8	Kharif

ORGANIC MAIZE PRODUCTION TECHNOLOGY FOR NORTH EASTERN REGION OF INDIA

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Organic agriculture is holistic production management system which promotes and enhances agro-ecosystem health, including biodiversity, biological cycles, and soil biological activity. Organic production systems are based on specific and precise standards of production which aim at achieving optimal agro-ecosystems which are socially, ecologically and economically sustainable. IFOAM defines “organic agriculture” as: “a production system that sustains the health of soils, ecosystems and people. It relies on ecological processes, biodiversity and cycles adapted to local conditions, rather than the use of inputs with adverse effects. Organic agriculture combines tradition, innovation and science to benefit the shared environment and promote fair relationships and a good quality of life for all involved.”

National scenario of Organic Agriculture

India is bestowed with lot of potential to produce all varieties of organic products due to its diverse agro climatic regions. An inherited tradition of organic farming in several states of the country is an added advantage. This holds the promise for organic producers to tap the market which is steadily growing (15 to 25 %) in the domestic market related to the export market. Farmers living in lands untainted by pollutants and away from the hassles of modernity and are rediscovering the benefits of traditional and holistic farming that maintains soil health and biodiversity. Currently, India ranks 10th among the top ten countries in terms of cultivable land under organic certification. The certified area includes 10% cultivable area with 0.50 million Hectare and rest 90% (4.71 million ha) is forest and wild area for collection of minor forest produces. The total area under organic certification is 5.21 million ha in 2012-13 (APEDA, 2014). India produced around 1.34 million MT of certified organic products which includes all varieties of food products namely Sugarcane, Cotton, Basmati rice, Pulses, Tea, Spices, Coffee, Oil Seeds, Fruits and their value added products. The production is not limited to the edible sector but also produces organic cotton fibre, functional food products etc. Among all the states, Madhya Pradesh has covered largest area under organic certification followed by Rajasthan and Uttar Pradesh.

India exported more than 300 organic products under 19 categories for a volume of 69837 MT realizing value of USD 157 million (2010-11). The major products exported were cotton & textiles-17363 MT (25 %), basmati (5243 MT) and non-basmati rice (1634 MT) (10%),

Oil crops-17966 MT (26%) except sesame-2409 MT (3%), Process foods -8752 MT (13 %), tea-2928 MT & coffee (5%), honey-2408 MT (3%), dry fruits -1472 MT (2%), spices, medicinal plants and their processed products, miscellaneous (13%). The other products categories (5%) are cereals, spices, medicinal and herbal plants, coffee, vegetables, aromatic oil and pulses. 44 % of the organic products were exported to Europe followed by Canada (22%), USA (19%) and Asia (13%).

Scope of Organic Farming in North Eastern Hill Region

The North-Eastern Region (NER) of India is organic by wisdom and farmers of the region are practicing organic farming since centuries with indigenous knowledge systems. It is probably the most suitable area of India for organic agricultural farming because of its number of odd advantages. This region is said to be, by and large, organic by default or the farmers of this region are *de facto* organic producers. The farmers have retained traditional practices and have shown an inclination towards organic farming that is being harnessed for the development of the region with ecological benefits. It is estimated that 18 million hectare of such land is available in the North-East, which can be exploited for organic production (Ramesh *et al.*, 2005). Among the North-eastern states Sikkim and Mizoram are two states in the region that have embraced organic farming in a big way by saying no to chemical fertilizers and pesticides. Sikkim has become one of the leading states in organic farming by bringing under the organic certification process over 60,000 hectare land. Mizoram has over 12,000 hectare area cultivated under organic certification process, while in Assam over 2,000 hectare has been cultivated under the organic certification process. With the sizable acreage under naturally organic/default and low usage of chemicals in farming, organic cultivation in the North-East has tremendous potential to grow crops organically and emerge as a major producer of organic products thus making the entire region a global organic agriculture hub. There is lot of scope for organic agriculture in the hills especially in the NEH Region of India. **Firstly**, the use of inorganic fertilizers and chemicals is meager in the region. The farmers of the region, in general and hill farmers in particular are having apathy towards use of agro-chemicals. In NER of the country, the application of chemical fertilizer is very low viz, 2.9 kg /ha in Arunachal Pradesh, 3.8 kg/ha in Nagaland, against all India average 141.3 kg/ha. Similarly, the use of pesticides in the region is very low because the farmers are practicing traditional methods for controlling of insect pests and diseases. Consumption of pesticides in Nagaland and Sikkim is nil. However, Mizoram and Meghalaya, consumption is only 13 tonnes. India's pesticides consumption is 43000 tonnes whereas, north-eastern region has only 141 tonnes (Anonymous, 2003). **Secondly**, the fruits of green revolution could not benefit the farmers of the hills as the system of production in the hills remained low input-low risk-low yield technology based and the average yield of most of the crop remained far behind. It is assumed that the difference in production gap due to adoption of organic agriculture is expected

to be negligible; rather there is scope for enhancing productivity with good organic management, the 6 organic premiums would boost earning of the hill farmers. **Thirdly**, it is an added advantage that all the households are maintaining livestock (pig, poultry, cattle, goats, etc.) producing sufficient quantity of on-farm manures, which could be efficiently used for organic agriculture. Moreover, the north eastern states being the one of the mega biodiversity receiving very high rainfall (2000 mm to 11000 mm per annum) leads to profuse production of biomass including weeds, shrubs and herbs. Some of these species could be efficiently used in organic production. Bujarbaruah (2004) reported that the region has a potential of about 47mt of organic manure including 37mt from animal excreta and 9 million tons from crop residues.

ORGANIC MAIZE PRODUCTION

Maize (*Zea mays* L.) is one of the most important cereal crop in the world used as food for humans and feed for animals. It has very high yield potential, there is no cereal on the earth which has so immense potentiality and that's why it is called 'queen of cereals'. Maize is grown in almost all the states of India (Layk et al., 2016). It is next to rice, wheat and sorghum with regards to area and production in India. It is the second largest producing cereal crop of the North Eastern Hill (NEH) region and Maize is the most potential and predominant rainy season crop in the hills of North Eastern Region (NER) of India (Das et al., 2010). Maize is cultivated in an area of about 0.17 M ha with productivity of 1.50 t/ha in the region, which is below India's national average productivity of 2.5 t/ha. The low maize productivity is mainly due to inadequate plant nutrition and cultivation of local cultivars (Layek et al., 2015). Organic food production is gradually gaining momentum worldwide. The recycling and the use of nutrients from organic manure have been given more consideration for ensuring sustainable land use in agricultural development. Maize is primarily grown under jhum land and terraced area and is very popular in the low- and mid-hill areas of the western and NEH regions. 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. However, maize productivity of NEH region is much below the national productivity. The low maize productivity mainly follows from inadequate plant nutrition and cultivation of local cultivars (Das et al., 2010). The farmers of the region have small and marginal holdings (Das et al., 2014) and cultivate maize, mainly in uplands and sloping lands. Organic farming is considered as one of the best option for protecting and sustaining soil health and produce healthy food (Das et al., 2010). Higher levels of total soil organic carbon (SOC), total nitrogen (N),



Figure 1. A general view of organic maize field at ICAR Complex, Umiam, Meghalaya

soluble phosphorous (P) and microbial activity were reported from soils under organic production system (Mader et al., 2002). Organic manure increases soil productivity by enhancing the soil's physical, chemical and biological properties (Patel et al., 2014). Although grain yields under organic farming is often lower than that under conventional farming, it is feasible to have increased yields under the former especially in hills. In view of growing demand for organic food products worldwide including India, the NEH of India has vast opportunity to emerge as major suppliers of organic products.

Package of practices for Organic Maize Production for NE Region

For getting desired result from organic farming, organic input responsive varieties are to be identified. Thus necessitating the need for identifying suitable maize cultivars along with location specific package of practices for sustainable organic hill agriculture. Hence, field experiments were conducted at the Agronomy Research Farm, ICAR Complex, Umiam, Meghalaya under Network Project on Organic Farming (NPOF) to identify suitable maize cultivars having short duration and high yield potential under organic production system over the years. Results revealed in ICAR Umiam, that yield attributes and yield of maize were significantly influenced by varieties under organic production system. The longest cob length was recorded with DA 61A followed by local yellow over the years and the shortest cob length was recorded in the local white. Cob weight was maximum in DA 61 A followed by RCM-76. Green cob yield was maximum in variety RCM 1-3 (5.73 t/ha, 5.91 t/ha in year 2013 and 2014, respectively) followed by RCM 1-1. The highest grain yield was recorded in DA 61 A (3.33 t/ha and 3.39 t/ha, in year 2013 and 2014, respectively) followed by RCM- 76 (3.26 t/ha and 3.29 t/ha). Lower grain yield was recorded in local white (2.62 t/ha and 2.67 t/ha in year 2013 and 2014, respectively). Correlation of grain yield of maize with cob length and cob weight also showed positive co-relation. The highest correlation was observed between grain yield and cob length followed by that between grain yield and cob weight. Thus, it is important that while selecting for high grain yield, due weightage is given to these yield attributing characters. The harvest index determines how much photosynthates are transformed into economic yield. The harvest index was recorded non-significant among the varieties. However, the highest harvest index was found in the variety DA 61 A. Whereas, the minimum harvest index was found in the local variety local yellow and local white. As harvest index indicates the ratio between the economic parts (i.e., in this case seeds) and total biomass production, varieties



Figure 2. Varietal evaluation of maize under organic farming

producing higher seed yield have recorded higher harvest index as compared to others (Layek *et al.*, 2014).

Experiments on crop establishment techniques (spacing, seed rate, sowing methods etc.), nutrient management, pest and disease management, weed management etc. on maize under organic farming were asunder taken for lase several years. Experiments on intercropping as well as sequential cropping also undertaken at ICAR Umiam research farm to identify the suitable crop can be gown successfully with or after maize. The standardized organic maize production techniques have been demonstrated in our several adopted organic villages in Meghalaya under NPOF project and the performance of maize in villages is highly satisfactory.

The standardized organic maize production technology for the region in summarized below.

Soil and Climate

Maize is best suited in well drained sandy loam to silty loam soils. Water stagnation is harmful to the crop, therefore, proper drainage is a must for the success of the crop especially during *kharif* season. Maize is warm weather plant. It grows from sea level to 3000 m altitude. It can be grown under diverse conditions. It is grown in many part of the country. *Kharif* season is the main growing season in NER of India. Maize can be sown any time from April to June in the *kharif* season in the region. The most suitable temperature for germination is 21 °C and for growth 32 °C. Extremely high temperature and low humidity during flowering damage the foliage, desiccates the pollen and interferes with pollen germination. Early sowing facilitates the successful cultivation of second crop like Frenchbean etc.

Varieties

RCM1-1, RCM 1-2, RCM 1-3, DA 61-A, RCM 75, RCM 76, Vijay Composite, HQPM-1, HQPM-2, Ganga-11, Ganga-2

Baby corn: HM-4, VL-42, Prakash

Land Preparation

Land should be ploughed 2-3 times to a depth of 20-25 cm. Planking should be done after each ploughing. A properly levelled and uniformly graded field is required for good water management. Good drainage should be provided in maize field, because stagnation of water in the field is harmful to the crop.

Seed rate and Spacing

Optimum plant population about 60-80 thousand per hectare would be needed to attain optimum yield. Maize seed should be planted at 50-60 cm row to row and 20-25 cm plant to plant spacing. Seed rate 20-25 kg/ha is sufficient for sowing of one hectare land. Maize seed should be sown at a depth of 5-7 cm. For baby corn spacing between plant to plant can be reduced to 10 cm for accommodating more number of plants with increased seed rate of 30 kg/ha.

Time of planting

Date of planting will differ from place to place. *Kharif* season maize should be sown two weeks before the onset of monsoon, where irrigation facilities are available. In rainfed, condition, the sowing of maize is generally done with the onset on rains. The optimum time of sowing for *kharif* maize in different agro climatic regions is as follows

Agroclimatic region

North-western hills

North-eastern hills

Peninsular region

Indi-gangetic plains

Sowing Time

April to early May

April-May

May-June

June –July

Manures and Fertilizers

Manures and fertilizers both play important role in the maize cultivation. Maize seed should be inoculated with N fixing microorganisms like *Azospirillum*, *Azotobacter*, etc. and phosphorus solubilizing bacteria (PSB) at 20 g/kg seed. Well decomposed FYM at 15 t/ha should be applied 20 days before sowing of crop with 150 kg rockphosphate. Crop residue of maize plant after harvesting should be incorporated in the field. FYM doses can be reduced up to 10 t/ha if vermicompost is applied @ 2-3 t/ha along with rockphosphate @150 kg/ha. Neem cake can also be added @150 kg/ha to the field for effective control of soil borne insect pests. Maize plant should be intercropped with legume crops or legumes should be incorporated in the cropping systems. Green manuring (*Dhaincha*) and green leaf manuring (*Tephrosia*) are also very good source of plant nutrients to be incorporated into the soil.

Earthing up

One earthing up may be given along with first weeding at 30-35 days after sowing to protect the plant from lodging.

Water Management

Maize is very sensitive both to excess water and moisture stress. Never allow water to stand in a maize field during its life cycle. Water stagnation even for 6-7 hours continuously can damage the crop. Maize can tolerate heavy rains provided water does not stand in the field for long periods. Therefore, drain out excess water by making drains of adequate capacity at the lower end of the field. A good crop of maize require about 500-600 mm of water during its life cycle. Tasseling and silking are the most critical stages for irrigation. At critical growth stage, water shortage even for 2 days can reduce maize yields by about 20 per cent.

Weed Management

In *kharif* season weed problem is more due to abundant rainfall. Weeds emerge with the germination of maize seeds and grow along with plants till the early growth period. This causes severe crop-weed competition. Failure of timely weed control results in heavy loss of crop yield. Mechanical weeding should be done 15-20 days after sowing of maize, which provides aeration to soil and also manages the weeds. Second weeding (Hand weeding) is done after 30-35 DAS and third after 50-55 days sowing. Intercropping with soybean (2:2) and mulching in between two rows of maize with weed biomass (*Eupatorium* spp.) after earthing up also manages the weeds.

Cropping System

Intercropping

It is better to grow a legume as intercrop in maize. In high altitude, Maize + soybean (one row of soybean in between two rows of maize) is very good intercropping practice for the region. In maize + soybean inter cropping, soybean detopping is necessary in high rain fall area, which adds 8-10 kg N/ha and also improve the productivity of soybean. In mid and low altitude area Maize + arhar (1:1 ratio) or Maize + groundnut/soybean and maize + rice bean is highly promising intercropping system. Paired row planting (2:2 row ratio) should be done for intercropping by adjusting spacing of the maize crop.

Cropping sequence

- High altitude** - Maize + soybean-French bean/Carrot/tomato
- Mid & low altitude** - Maize-French bean, maize- mustard and maize-vegetables
Maize-pea (for vegetable purpose, 70 days duration)
Maize (fodder)-Rice (early variety sown at the end of June)
Maize + Soybean (2:2)- mustard

Plant protection

Insect pests

Maize cob borer, stem borer, cut worms are the major insect pest of maize. Use of resistant/tolerant varieties (RCM 1-1 and local yellow are tolerant to cob borer) and timely sowing reduces the problem of disease and pests. Summer ploughing exposes the larvae of insect pest to natural predators like birds. Eggs of insect (Grasshoppers, crickets, etc.) also get exposed to sunlight and get killed. Burn the stubbles of infested crop to reduce the problem. *Trichogrammaspp.* @ 50000 nos. per ha is suitable for most of the insect pest. Spraying of derisome (product of *Derrisindica*) or neem oil @ 3 ml/l of water at 20-25 days after germination checks stem borer, cut worms and army worms. Spraying of lantana extract 10% and panchgavya 3 % control most of the insect pests. Application of neem cake @150 kg/ha in the field is effective against soil borne insect pests like cut worm. Derisom 3 ml/l + *Panchagavya* 3% + cow urine 3% is effective in managing most of the insect pests of maize under organic production system.

Diseases

Turcicum leaf blight, maydis leaf blight and rust are the major diseases of maize. These can be managed by using resistant/tolerant varieties like MCU-9, COM-1, Vaimindum (local var. of Mizoram), Local yellow, Local white, Vijay, MCU-204, MCU-314. Spraying the crop for 3 or 4 times at 15 days interval with neem oil/ derisom @ 3 ml/lit + panchgavya 3% + cowurine 3% is effective in managing most of the diseases and also supply some nutrients to the plants. Preventive measures like collection and destruction of all infested plant materials after harvest and crop rotations with non-cereal crops preferably legumes should be followed to manage diseases effectively.

Harvesting

Crop should be harvested by removing the mature cobs from the plants and keeping the standing stalks in the field itself for putting as mulch in succeeding crop. In baby corn, harvesting of cobs should be done immediately after emergence of the silk. Five to six harvesting can be done at two days interval in baby corn.

Shelling

Use maize sheller developed by the ICAR Research Complex for NEH Region, Umiam, Meghalaya for shelling the dry cobs to save money, time and it also increases efficiency of labourers. After shelling seed should be sundried to keep the grain moisture at 10-12 %.

Yield

A good crop of maize produces a grain yield of about 4.0 to 5.0t/ha under organic production system.

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PARTICIPATORY MAIZE SEED PRODUCTION IN NEH REGION: STATUS, SCOPE AND STRATEGIES

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Maize (*Zea mays* L) is one of the most versatile emerging crops having wider adaptability under varied agro-climatic conditions. Globally, maize is known as queen of cereals because it has the highest genetic yield potential among the cereals. It ranks as the third most important food grain crop in India. The maize area has slowly expanded over from 3.16 m ha in 1950-51 to 8.69 m ha in 2016-17 with a 2.75 fold increase in area (Fig.1). The productivity has increased 4.6 fold and hence the production has faced an unprecedented growth of 12.60 times. In India, maize is grown in a wide range of environments, extending from extreme semi-arid to sub-humid and humid regions. The crop is also very popular in the low- and mid-hill areas of north eastern regions of India. Yet the productivity of maize in NEH regions of India is lagging behind the national average of 2509 kg/ha. Except Manipur (2243 kg/ha) and Meghalaya (2259 kg/ha) the other states have shown very low productivity.

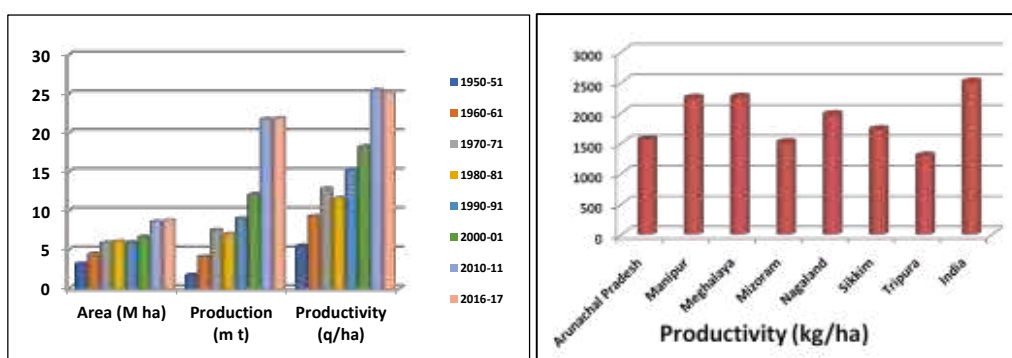


Figure.1 Maize cultivation scenario of India

There are several reasons for low productivity of maize in NEH region listed as follows-

- 1) Seed availability of high yielding varieties
- 2) Erratic distribution of rainfall induced intermittent moisture stress in the rainfed upland condition
- 3) Soil acidity
- 4) Cultivation of maize by resource poor small and marginal farmers
- 5) Small and fragmented land holdings
- 6) Marginal farm mechanization due to high slope gradients

Among these, use of quality seeds, along with proper management practises, is the most essential and cost-effective way to increase the crop production and productivity. In other words, enhancing seed replacement ratio with the continuous supply of high yielding varieties/hybrids should be accorded high priority in achieving the goal of a highly profitable agriculture. The shortage of seeds of desirable varieties in this part of country is the major bottleneck towards increasing the productivity.

During last 10 years, a number of varieties/hybrids have been developed in maize with a yield advantage of 10-40% over local cultivars with better resistance to biotic and abiotic stresses. To boost the productivity of maize in this part of country, farmers need to have access to improved seeds of these varieties/hybrids at the right time, at the right place and at a reasonable price. For the supply of such seeds, the informal seed sector (namely, farmer managed seed, seed village programmes, Farmers' Participatory Seed Production and farmer seed distribution system systems) and the formal seed system (seed enterprises) have a great role to play. The informal seed sector is found to be effective in quickly reaching out to the difficult, inaccessible, small holder pockets and would be a sound alternative for entrepreneurs to gradually evolve into the formal enterprises.

Selener (1997) argues that farmer participatory research consists of seven elements. The first element is the inclusion of resource poor farmers in making decisions about the generation of technologies that solve their felt problems. Second, farmers participate in the identification of problems, needs, opportunities, priorities, design and implementation of experiments and in the evaluation of results. Third, research is conducted in the farmer's field. Fourth researchers work and learn with farmers, facilitating and providing support. The fifth element is that FPR is based on a systems perspective that requires an understanding of the entire system. Sixth, FPR involves interdisciplinary collaboration and dialogue between farmers and agricultural and social scientists. Finally, FPR is broad, flexible and adaptive to changes in hypotheses, needs, and local conditions over time.

In this regard 'one village-one variety' concept may be promoted for maize seed production. However, in the case of simultaneous multiplication of short- and long-duration varieties in the same village, time isolation can be effective. Before the start of the cropping season, farmers' meetings have to be organized to decide on the seed production program. Based on the size of their farm holdings, seed production of maize has to be decided by the farmers themselves in each village. The following activities will be effective to develop farmers' capacity in quality seed production, processing and marketing by facilitating the formation of their associations.

1. **Farmers' training in crop management and seed production-** This includes varietal description, seed treatment and sowing methods, agronomic practices, weed management, water management, integrated nutrient and soil management, integrated

insect pest and disease management including biological control methods, isolation distance and rouging in seed production plots, postharvest technology, value addition etc.

2. **Linkage with formal seed sector-** The interested seed farmers should be linked with the State Seed Certification Agency for seed certification and the public sector seed agencies such as National Seeds Corporation Ltd. (NSC Ltd.) to strengthen the formal seed sector for seed production. Linkage with Krishi Vigyan Kendra will provide day to day technical backstopping to farmers and ensure quality of seed produced.
3. **Seed processing at local level-** The units/instruments which clean, grade, weigh and pack the seed should be demonstrated locally among the farmers. Young farmers should be given one-day training in the operation and maintenance of the mobile seed processing machine. If for any reason these machines cannot be handed over to the village societies, would be available to the societies on a custom hiring basis.
4. **Formation of farmers' cooperative societies-** Farmers' cooperative society needs to be formed following the guidelines/requirements of the Registrar of the Cooperative Societies. The major purpose is to promote community participation in agricultural and seed production activities in a self-sustainable manner to ensure seed sufficiency not only at the village level but also in adjoining areas. Each society needs to be trained in procurement of basic seed (Breeder seed) from the public sector research institutions, production of quality seed and its processing, bagging, labeling, storage and marketing in the same or neighboring villages and districts. Anybody can become a member of these societies by paying an annual membership fee. Each member of the society should have equal rights in the governance and management.

Implementation of participatory plant breeding program:

Along with seed production using participatory approach, there is a need to develop the varieties using the skills and needs of farmers in participatory manner. In the majority of plant breeding programs, most of the research and development programmes for varietal development occur in the Institute farm and only the final product enters into the farmers' fields. The varieties developed at the institute farm is expected to perform well in environments similar to the research stations but may not perform as well in the fields of resource poor farmers located at remote area. Thus, implementing a decentralized-participatory plant breeding requires the developmental programme at farmers' fields (Fig. 2). Also a part of the breeding materials can be grown on Institute farm to increase the visibility and thus, farmers can take decision decisions supplemented by research official. It is believed that during selection process at farmer's field, farmers also exchange information about the agronomic management of the trials, and rely

greatly on this information before deciding which entries to select. Therefore, the characterization of the breeding materials for their responses to environmental or agronomic factors starts at an early stage of the selection process. The effect of genotype x farmers' field can be assessed if the process can be repeated in several villages having difference in elevation, rainfall pattern and temperature.

Developing a network of participating farmers is the basic methodology for participatory seed production *vis a vis* participatory plant breeding. A process of scaling-up with the following steps can be quite useful:

- 1) Meeting of all the stakeholders (farmers, researchers, extension staff, seed production organizations and policy makers) at the beginning of the process to discuss the various aspects of participatory seed production *vis a vis* participatory plant breeding and the responsibility of each of the stakeholders.
- 2) The creation of local teams with scientists, extension staff and farmers participating in all major steps of seed production as well as varietal development, by maintaining specific responsibilities. This will replace the traditional linear sequence scientist → extension → farmers by a team approach for scaling-up.

Impact of PPB



Figure.2 Comparison of conventional breeding method with participatory approach

In a conventional breeding program, the certified seed reaches the farmers and only then farmers decide whether or not to adopt them. If farmer is unwilling to adopt the variety then it will be a serious loss to the resources of the nation. This can be visualized by number of varieties

being released and only a small fraction being adopted by the farmers. With PPB, it is the initial farmers' adoption which drives the decision of which variety to release. As a consequence, adoption rates are expected to be higher, and risks are minimized, as intimate knowledge of varietal performance is gained as part of the selection process. A breeding program organized according to these principles will have the advantages of producing environmentally-friendly varieties and of maintaining or even enhancing biodiversity.

Conclusion

Participation of farmers in the cultivation of varieties developed by plant breeders is crucial for their successful adoption. This not only gives credit to the plant breeder responsible for developing that variety but also provides enough scope for income generation and improving the livelihood of the farmers. Thus, in order to achieve the goal, a straight forward strategy is to directly involve the farmers in growing and seed production of variety.

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MAIZE FOR FEED AND FODDER: STATUS, SCOPE AND OPPURTUNITIES

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On worldwide basis, much of the maize produced is fed to livestock, whereas only a small portion goes directly to human food. Maize contributes greatly in meeting the energy requirements of livestock. Their quality depends on seasonal and storage conditions. Poor growing or storage conditions can lead to grains with a lower than expected energy content or contamination with mycotoxins or toxin-producing organisms. Environmental factors also affect the nutrient content in grains and the digestibility of nutrients contained in an ingredient. The grain provides the world with 19% of its food calories and 15% of its annual production of food crop protein. Maize provides more feed for livestock than any other cereal grain. For instance, 65% of the maize grown worldwide is used for livestock feed, of which the United States is the highest consumer. Also, rapid increase in poultry production in developing countries in Latin America, Africa and Asia is a major factor contributing to the increased use of maize for livestock feeding. In fact, maize is the preferred grain for feeding domestic birds, because its dietary energy value is the highest among cereals with very low variability between years for a given region.

Carbohydrate content of maize grain

The relative proportions of the various carbohydrates are 77% starch, 2% sugars, 5% pentosans and 1.2% crude fibre. The carbohydrate which forms more than 70% of the maize grain is concentrated in two starchy fractions, floury and flinty, of the endosperm. The sugar in the grain is found in the germ and dietary fibre is in the bran. The endosperm consists of starch granules embedded in a protein matrix. Flinty endosperm has a more rigid protein structure and is also higher in protein content than floury endosperm. The starch in the flinty endosperm consists of 100% amylopectin (large branched molecules), whereas that in the floury endosperm comprises about 27% amylose (linear molecules) and 73% amylopectin. This variation in starch structure does not have any effect on the nutritional value of maize for poultry. The distribution of flinty or floury endosperms in the maize grain determines whether a maize variety is classified as flint or floury (dent) maize. The starch which is the main source of energy in the grain has a digestible energy content ranging from 3.75 to 4.17 kcal/g dry matter, thereby making maize one of the highest in energy among the cereal grains.

Table 1: Nutrient composition of Corn and its by-products

Ingredient	DM	Energy	CP	EE	CF	Ca	Met	Lys
Yellow corn	86	1540	7.5	3.5	1.9	0.01	0.18	0.24
High oil corn	87	1615	8.4	6.0	2.0	0.01	0.20	0.28
Corn germ meal (wet milled)	90	770	20.0	1.0	12.0	0.30	0.60	0.90
Corn germ meal (dry milled)	91	n/a	17.7	0.6	10.9	0.03	0.43	1.10
Corn gluten feed	88	795	21.0	2.0	10.0	0.20	0.50	0.60
Corn gluten meal, 41%	90	1510	42.0	2.0	4.0	0.16	1.00	0.60
Corn gluten meal, 60%	90	1700	60.0	2.0	2.5	0.02	1.90	1.00

DM = Dry matter, %; Energy in kcal/lb; CP = Crude protein, %; EE = Crude fat (ether extract), %; CF = Crude fiber, %; Ca = Calcium, %; Met = Methionine, %; Lys = Lysine, %

Protein content of maize grain

The maize grain is deficient in protein, but its variability is low with standard error of the order 7 g/kg of crude protein. The protein content of maize grain ranges from 8 to 11 g/100 g grain of dry matter. The various fractions of grain vary considerably in protein content. Even though the majority of protein in the grain occurs in the endosperm, the germ (184 g/kg DM) is considerably higher in protein content than the endosperm (80 g/kg DM). Generally, the low protein content of the grain limits its nutritive value as the only source of food for both humans and livestock.

Vitamin content of maize grain

Analysis of the vitamin content of maize indicates that the grain furnishes significant quantities of riboflavin, panthothenic acid, choline and pyridoxine which are sufficient to satisfy the requirements of most livestock. However, the most significant feature of the vitamin pattern in maize is the low niacin content. Besides, much of niacin that occurs in the grain is in a bound form (niacytin), which is not available to monogastric animals. Furthermore, the high level of the essential amino acid, leucine, in the maize grain increases niacin requirement in humans. Thus, people who live only on a diet of maize suffer from the disease pellagra, associated with niacin deficiency. Nevertheless, niacin shortage alone would not cause pellagra if normal maize were rich in tryptophan or heat- treated with alkali. One approach for improving niacin intake in maize- based diet is complementation with either legumes or animal products.

Mineral content of maize grain

The inorganic or mineral component (ash) of maize grain constitutes less than 2%. Of this, about 75% is found in the germ. The grain is most abundant in phosphorus and potassium, but deficient in calcium and trace minerals except iron. Much of the phosphorus, however, is present in the form of phytic phosphorus which is not digested by monogastric animals. The little calcium that is normally present also has low bioavailability because it forms complexes with phytic phosphorus.

Corn By-products

Maize (corn) distiller's dried grains with solubles (DDGS) are a by-product of the dry-milling process used in ethanol production. Each bushel of corn (25.4 kg) fermented in a dry-mill ethanol plant will produce approximately 9.1 liters of ethanol, 8.2 kg of carbon dioxide, and 8.2 kg of DDGS. Yellow dent corn is most commonly used to produce ethanol and DDGS because it is an excellent source of readily fermentable starch. Corn contains approximately 62% starch, 3.8% corn oil, 8.0% protein, 11.2% fiber, and 15% moisture. Because most of the starch is converted to ethanol during fermentation, the resulting nutrient fractions (protein, oil, fiber) are 2 to 3 times more concentrated in DDGS compared to corn. Dry-mills produce DDGS, but wet-mills produce corn gluten feed, corn gluten meal, and corn germ meal. During wet milling of corn, the delivery of shelled corn is cleaned and then soaked in steep tanks. This softens the kernels. While the kernels are being soaked, nutrients are dissolved into the water. This water is later evaporated to concentrate the nutrients, resulting in the production of condensed corn fermented extractives. The remaining corn kernels are further processed to remove the germ. The germ can be further processed to remove the corn oil. The remaining portion is referred to as the corn germ meal. The wet processing of the corn kernels continues with screening of the bran, which leaves the starch and gluten. The bran is combined with other coproducts to produce corn gluten feed. The starch and gluten slurry is then centrifuged so that the starch sinks to the bottom and the lighter gluten floats to the top. The gluten is then dried to form corn gluten meal. The starch can be further processed to produce dried corn starch for use in the food, paper, and textile industries.

Feeding of maize as an energy source in livestock feed

As livestock feed, maize is the grain that is most important. The stalks, leaves and immature ears are used as forage for ruminants. Maize grain is recognised as giving the highest conversion of dry matter into meat, milk and eggs in relation to other cereal grains. It is used extensively as the main source of calories in the feeding of poultry, pigs and cattle. Maize, therefore, is popular for feeding monogastric animals, particularly poultry.

Poultry

In the feeding of poultry, maize grains are either fed directly or are milled and compounded with other ingredients and thoroughly mixed. The mixture is then fed or converted into forms most desired by specific animals. The by-products obtained from both wet-milling and dry-milling industrial processes of maize grain are potential feed ingredients for poultry. The major by-product ingredients include the germ, bran and gluten. These by-products of maize are usually mixed to produce a feed ingredient called maize gluten feed. Despite the nutritional potential of maize gluten feed as a feedstuff for poultry, its use has been minimal due variously to paucity of research information available, perceived low metabolisable energy content and unknown quality of the protein even though the protein content is fairly high.

Although the amounts and types of cereal grains included in poultry diets will depend largely on their current costs relative to their nutritive values, care must be taken to avoid making large changes to the cereal component of diets, as sudden changes can cause digestive upsets that may reduce productivity and pre-dispose the birds to diseases. Maize is an excellent feed ingredient for both meat and egg laying birds and is extensively used as an energy source. It is high in energy but low in protein. The available protein in maize is of poor quality because it is deficient in both tryptophan and lysine, hence the need to provide supplemental amino acids. Most hybrid varieties tend to produce grain of lower protein content than the oldopen-pollinated varieties. Yellow maize has higher protein content and contains yellow pigmentation that helps in producing yellow egg yolks and yellow-fleshed broilers. Yellow dent corn is the variety typically used in feed. Corn has about 1520 kcal/lb (3350 kcal/kg) of energy for poultry. It also has, on average, 7.5% crude protein. Corn protein is low in methionine much of the phosphorus in corn grain is bound to phytate (</pages/65417/phytate>) and is not readily available to birds. Birds do not produce sufficient phytase, which is the enzyme required to break down phytate and release the bound phosphorus. Phosphorus availability can be increased by the addition of the enzyme phytase to feed.

The list that follows outlines the average nutrient content of corn:

- Dry matter: 86%
- Metabolizable energy: 3350kcal/kg (1520 kcal/lb)
- Crude protein: 7.5%
- Methionine: 0.18%
- Cysteine: 0.18%
- Lysine: 0.24%
- Tryptophan: 0.07%
- Threonine: 0.29%

- Crude fat: 3.5%
- Crude fiber: 1.9%
- Ash: 1.1%
- Calcium: 0.01%
- Total phosphorus: 0.23%
- Non-phytate phosphorus: 0.09%

Swine

Maize (*Zea mays*) sometimes referred to as corn and related products have been popular ingredients in swine diets for many years. Lysine and tryptophan are the first and second limiting amino acids, respectively, for swine. The reason for the poor quality of the protein is that zein, the main storage form of protein in the kernel, is a poor source of many essential amino acids. There are efforts to use maize cobs as an animal feed because of the high competing demands with humans for the grain. Maize cobs, a by-product of a major cereal grown worldwide, have potential to be used as a pig feed ingredient. Presently, maize cobs are either dumped or burnt for fuel. The major challenge in using maize cobs in pig diets is their lignocellulosic nature (45% to 55% cellulose, 25% to 35% hemicellulose, and 20% to 30% lignin) which is resistant to pigs' digestive enzymes. However, grinding, heating and fermentation can modify the structure of the fibrous components in the maize cobs and improve their utilization. When treated and fed, corncobs can enhance the growth performance of weaner/grower pigs. The diet is relatively easy to prepare and when used up to 20%, it offers the most efficient and cost effective diet for pigs. When properly disseminated, this ration can cut down on feed cost to farmers. Pigs can also extract up to 25% of energy maintenance requirements from fermentation products. In addition, dietary fiber improves pig intestinal health by promoting the growth of lactic acid bacteria, which suppress proliferation of pathogenic bacteria in the intestines.

Mycotoxins impact on feeding corn in swine

Perhaps the greatest concern surrounding the use of corn in swine diets is its susceptibility to molds, especially when wet weather arrives during critical growing stages. When the mold produces mycotoxin, such as vomitoxin or zearalenone, the effects on swine can be very serious. Reproductive performance of sows appears to be most susceptible, so that some pork producers have switched to barley-based diets for the breeding herd.

Dairy cows

Maize is a high energy grain that can be used to improve dairy cow production and reproductive performance. The higher energy content of maize grain means that it can be used to lift per cow energy intake and milk production more effectively than lower energy supplements.

This means that farmers can afford to pay more for maize grain on a per kilo basis than lower quality concentrates. Maize grain has advantages for rumen health when compared to other concentrates. It has high starch content but virtually no soluble sugar. In addition maize starch is less rapidly degraded in the rumen than other starch types. This means that there is a lower risk of acidosis (grain overload) when feeding maize grain when compared to other grains (e.g. wheat) or high sugar feeds (e.g. molasses).

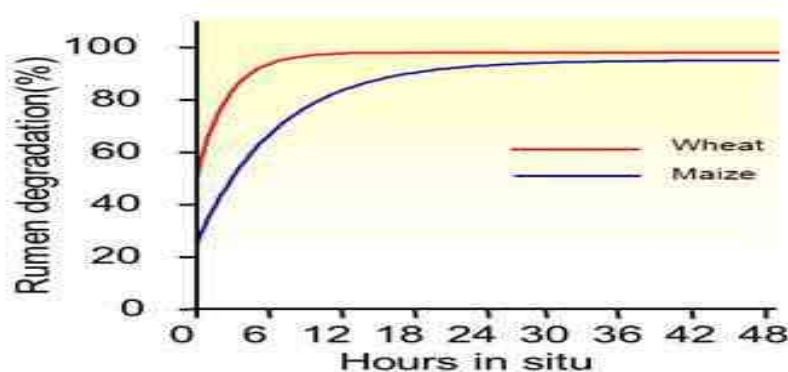


Figure 1: Rumen degradability of maize vs. wheat grain

Maize grain and milk protein

- When cows are fed starch or a sugar-based supplement more of the additional milk solids are protein and lactose.
- When cows are fed a fibre-based feed more of the additional milk solids is fat.
- Because milk protein is generally worth two to three times more than milk fat, this effect of supplement type has implications for the revenue generated from the supplement used.

Maize grain is an excellent option for feeding to dry cows as well as milking cows. As a concentrate, it has the advantage of lifting feed intakes when cows are being optimally fed and reducing the risk of substitution. Providing it is fed in conjunction with a good protein source (e.g. leafy pasture), maize grain is an excellent feed for young stock, promoting rapid rumen development meaning calves are able to be weaned on to grass quicker. Maize grain feeding rates will vary depending on the age and production level of the livestock and also the amount and type of other feeds in the diet. Current recommendations are for a maximum of 38% total soluble carbohydrate and 30% total starch in the whole diet (pasture plus supplements). As a general rule of thumb, for pasture-based diets, maize grain can be fed to a maximum of 30% of the total dry matter intake. Feeding rates will be lower when the diet contains other carbohydrate sources (e.g. other grains or meals, molasses or high carbohydrate byproducts, (for example kiwifruit and potatoes). No more than 2.5 kg DM maize grain should be fed in a single feed.

Future challenges of maize utilisation in livestock diets: The major future challenges confronting maize utilisation in livestock production include the following:

- Adverse effects of climate change on maize production have been reported in tropical and subtropical regions. These include frequent droughts, heat, increased temperature and inadequate rainfall during the growing season and water-logging. It has been estimated that one quarter of the global maize areas is affected by drought in any given year.
- Competition between humans and animal agriculture. Maize is increasingly being used for human food and other industrial purposes including biofuel production. Thus, in a world where the global population is continually increasing, the argument that producing feed for livestock conflicts with feeding hungry people is likely to continue for some years.
- Some challenges for widespread adoption of QPM (Quality protein maize) in developing countries have been described, which include lack of profitable markets for commercial producers and lack of government incentive to encourage adoption by subsidizing the price of QPM seed.

Maize Production in Hydroponics Green House:

Fresh Green fodder is an important component in the diet of livestock. Due to droughts, floods and other adverse climatic factors, the production to meet the demand of the fodder has become a challenge among livestock farmers. In recent years, the production of green fodders has decreased affecting livestock production and health. As the demand and supply of the green fodder for livestock is increasing, there is a need for alternative method for fodder production which would ensure fodder production throughout the year for betterment of livestock production.

The word hydroponics has been derived from the Greek word. Hydro means 'water' and ponos means 'working' and it is growing of fodder without soil but in water for a maximum of 6 days. The water must be safe for human drinking. You can sprout seeds of barley, maize, oats, wheat or sorghum to obtain fodder for cattle, pigs or poultry.

Benefits of Hydroponics grown fodder:

1. Fodder is produced within a short a time and in a small area.
2. Fodder is completely edible to livestock –they eat the entire mat, roots and green growth. There is no wastage of feed.
3. Water requirement is less and can be recycled.
4. Minimal running costs; soil preparation, weed control and post-harvest loss.
5. Minimal incidences of pests and diseases.

Current status of green fodder production in the country and the state

Category	India (Million hectares)
Total geographical area	328.7
Fodder crops	8.3
Green fodder deficit	60 – 65%

Protocol for producing maize green fodder in Seven days cycle in Hydroponics unit:

1. Select seeds without overgrowths and free of chemicals
2. Disinfect seeds by soaking in diluted chlorine solution (similar to what is used to disinfect drinking water) for 2 hours to prevent mould/fungus growth.
3. Drain chlorinated water and rinse grains then soak the grains in water for 24 hours to promote water uptake by the grains.
4. For grain sowing, measure 2kg of grains for each tray that measures 80cm by 40cm
5. Spread the grains on the trays evenly (not over 3cm deep) to provide enough space for each seed to sprout.
6. Ensure your tray has holes that are evenly spread at the bottom for proper drainage of water.
7. Transfer the trays to the hydroponic unit. Germination of seeds begins at this point and is considered day 1.
8. Irrigate from day 1 to day 6 at intervals of 4 hours in every 24 hours (30 seconds for automated system and 1 minute for manual system).

Feeding Hydroponics grown maize fodder to Livestock:

Cattle: Provide 8kg of the hydroponic maize fodder to replace 2.5kg dairy meal in addition to hay and silage.

Pigs: At fattening stage provide 3kg of hydroponic maize fodder and 2kgs of dry feed.

Poultry: For 100 layers provide 8kg of hydroponic maize fodder in addition to 4kg of layers mash per day.



Seven days hydroponics maize fodder



Harvesting of hydroponics maize fodder



Figure 2: Dairy cow and pigs relishing hydroponics grown maize fodder

Nutritional content of Hydroponics grown Maize:

Particulars	(% on as such basis)	(% on dry matter basis)
Moisture	86.75	-
Crude Protein	1.90	14.35
Crude fibre	1.79	13.54
Ether Extract	0.48	3.64
NFE	8.62	65.08
Ash	0.45	3.39

Hydroponics Maize grown fodder vs Conventional Farming:

Parameters	Hydroponics	Conventional farming
Control on Environment	Effective control	No Control
Yield	Predictable	Not Predictable
Budgeting	Easier	Not Effective
Aeration of Root	Can ensure adequate aeration of root zone	Cannot ensure
Pest and Diseases	Controlled	Not controlled
Temperature & Humidity	Automated	Not automated
Water Recycling	Can be recycled	Cannot be recycled
Labour costs	Low	High
Soil	Not required	Required
Water consumption	Low (70 to 80 % lower than conventional farming)	High
Space requirement	less space	More space

Low cost Hydroponics Green House:

There was a perception that hydroponics fodder can only be grown under Hi-tech nursery and green houses. However, the unit can be made using low cost locally available materials. The low cost unit can be fabricated with Bamboo and wood, MS or GI pipes and plastic pipes. For irrigation: Micro sprinklers (automatic or manually) or a Knapsack sprayer can be used at regular intervals. The cost of Greenhouse unit (30-350 kg fresh fodder capacity daily) made of shade net and wooden material is approximately Rs. 6000-50,000.00. The cost of Greenhouse unit (150-750 kg fresh fodder capacity daily) made of shade net and MS pipe material is approximately Rs. 25,000-1,50,000.00. Home grown or locally available seeds of maize, wheat etc., can be used in this low cost unit (Naik *et al.*, 2013).

Prospects of Hydroponics grown maize fodder for Manipur:

Hydroponics unit can be incorporated in Livestock based Integrated Farming Systems (IFS) as:

- ✓ Dairy cattle Based IFS Model
- ✓ Piggery Based IFS Model
- ✓ Buffalo Based IFS Model
- ✓ Goat Based IFS Model

Manipur is having a total bovine (Cattle, buffalo) population of 3,56,552. There is a huge prospect for low cost hydroponics unit for Dairy cattle farmers as the market cost of concentrated feeds is high. The hydroponics grown maize fodder can be used as a supplement in the diet of livestock's and poultry during scarcity season to increase the milk production, to minimize the cost of concentrated feeds and to improve the livelihood of small and marginal farmers.

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USES OF MAIZE STALK IN SILAGE PRODUCTION

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Maize (*Zea mays* L.) as a green forage, is an energy-rich feed for ruminant livestock. Maize is a high energy feed, better than most other tropical forage crops, of which dry matter is often below 40 % digestible. Forages can be made into hay to conserve the nutrients, especially protein, before they decline in the plant. However it is often too wet to dry the successfully and special machinery, has to be used to assist the forage to dry quickly. Forage crops such as maize, are too thick-stemmed to dry successfully as hay. Silage is considered the better way to conserve forage crops. A forage crop can be cut early and only has to have 30% dry matter to be ensiled successfully. There is no need to dry out the plant material any more than that, so wet weather is not such a constraint as it is with making hay.

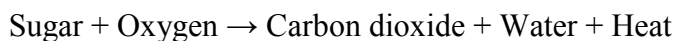
Ensiling maize forage is necessary in cooler regions where year-round maize production is not permitted. Maize are very suitable for ensiling (preserve green fodder) as they contain fermentable carbohydrates (sugar) necessary for bacteria to produce sufficient organic acid that acts as a preservative. Though leguminous fodders can also be used, they are rich in proteins and low in sugars making them a bit difficult to ensile. Silage ensures high milk production and healthy dairy animals, especially during dry seasons. It is palatable, laxative, digestible, and nutritious and requires less floor area for storage than hay.

Maize silage is the major source of maize forage for livestock, largely replacing green maize forage. It is one of the most valuable forages for ruminant livestock and it is used wherever maize can grow, from temperate regions to the tropics (Heuzé, *et al.*, 2017). The popularity of maize silage is due to several factors. It is a consistent source of palatable and high-energy forage for all classes of ruminants, including dairy cattle, beef cattle, sheep and goats (Roth *et al.*, 2001). It is one of the most high-yielding forage crops, requires less labour (since it is harvested in a single operation) and is generally less costly (per t DM) to produce than other forage crops (NASS, 2015; Arvalis, 2011 and Roth *et al.*, 2001). Maize silage is also a good way to secure the crops as it is possible to turn a maize grain crop damaged by frost, rain or drought into maize silage (Arvalis, 2011 and Roth *et al.*, 2001).

Though relatively easy to produce, maize silage requires good crop and harvest management as well as careful ensiling practices (Arvalis, 2011). Harvesting maize for making silage is ideal when their seeds are soft but not milky when squeezed open.

Principle

At harvest, plant cells do not die immediately, they continue to respire as long as they remain adequately hydrated and oxygen is available. The oxygen is necessary for the physiological process of respiration, which provides energy for functioning cells. In this process, carbohydrates (plant sugars) are consumed (oxidized) by plant cells in the presence of oxygen to yield carbon dioxide, water and heat:



Once in the silo, certain yeasts, moulds and bacteria that occur naturally on forage plants can also reach populations large enough to be significant sources of respiration. In the silage mass, the heat generated during respiration is not readily dissipated and therefore, the temperature of the silage rises.

Although a slight rise in temperature from 80-90°F is acceptable, the goal is to limit respiration by eliminating air (oxygen) trapped in the forage mass. Some air will be incorporated into any silo during the filling process, and a slight increase in silage temperature is likely. These temperature increases can clearly be limited by harvesting at the proper moisture content and by increasing the bulk density of the silage. Generally, it is desirable to limit respiration during the fermentation process by using common sense techniques that include close inspection of the silo walls prior to filling, harvesting the forage at the proper moisture content, adjusting the chopper properly (fineness of chop), rapid filling, thorough packing, prompt sealing and close inspection of plastics for holes.

Preparation:

Harvesting maize

Maize forage should be harvested at 30-35 % dry matter. The choice of harvesting time is a trade-off between yield, nutritive value and silage quality (Arvalis, 2011). The ideal harvesting time is when the plant has reached physiological maturity and is in the full dent stage. This generally occurs 50-55 days after cob silking and corresponds to a dry matter of 32-38 % in the whole plant. This can be correlated with two visual indicators in the grain, the milk line (limit between the dent part and the liquid part of the grain), and the black layer (that is visible at the base of the kernel once complete maturity has occurred). Optimal time is when the milk line of the grain is situated between 1/3 and 2/3 of the grain from the top (Figure 2) (Ashley, 2001). Once the black layer appears, the dry matter content is higher than 37% and the grain should be ground to prevent loss of digestibility (Ashley, 2001).

A lower or higher dry matter content may result in poor silage quality. Low dry matter content due to early harvest results in low dry matter silage which may be bulky, thus reducing feed intake and animal performance (Hicks *et al.*, 2004). A low dry matter content also results in nutrient losses (dry matter, water soluble carbohydrates and protein) during ensiling (leachates)

(McDonald *et al.*, 2002). A dry matter content of less than 30% increases the risk of bacterial and fungal spoilage (Johansson, 2011).

Harvesting too late can cause a low nutritive value of silage because of poor starch and fibre digestibility (Giardini *et al.*, 1976). Such silage may also have a low palatability, which may reduce DM intake (McDonald *et al.*, 2002). Late harvest may result in heating problems because of insufficient packing conditions (Nadeau *et al.*, 2010). To overcome this, late harvested maize silage should be finely chopped (UWEX, 2016).

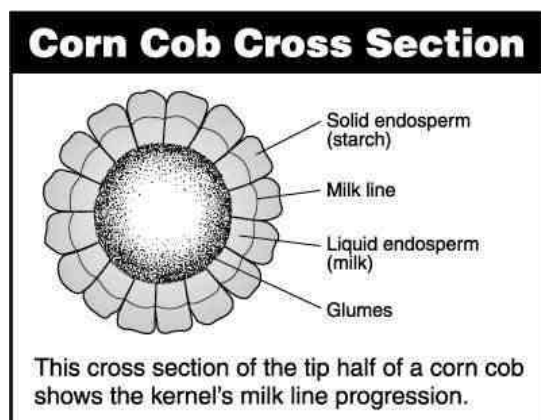


Figure 1. Corn cob cross section

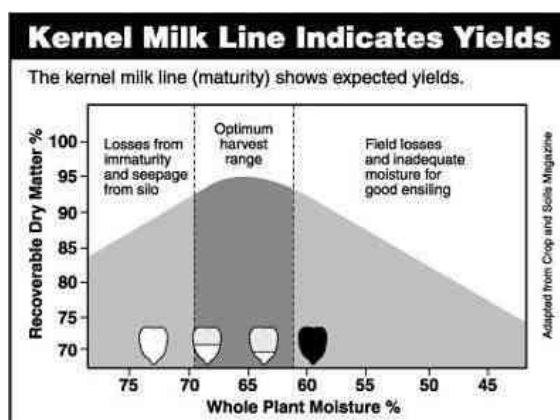


Figure 2. Progression of kernel milk line

Silage processing

Silage is a fermentation process aimed at preserving forage in its wet state away from air. It is produced through use of pits or trenches, towers and sacks for small quantities. However, pits are mostly used to prepare silage for large dairy units. The silage pit should be located at a place safe from rodents, away from direct sunlight and with higher elevation or slightly sloppy to avoid rain water entering into the facility. The ideal materials used in silage making should have a moisture content of 60-70 % or dry matter in the range of 30-35 % (tested by taking a small bundle of the fodder and wringing with two hands and if no moisture comes out, it is ready to ensile) and a pH below 4.2 for wet forage and below 4.8 for wilted forage. In rainy periods when the fodder is too wet, containing more than 70 % water, it is advisable to wilt it in the sun first.

Making silage from maize is popular and forage can be cut at the baby corn stage (as this stage will have highest nutrition values).

1. The foremost step is to choose the type of hybrid and perennial varieties of maize crops which can be grown in short duration and produced multiple times.
2. A dry place is then chose to dig the pit on slightly sloping ground and the depth of the pit should decrease from the higher side of the sloping ground to the lower side by giving wedge like shape. Usually, size and dimension of the pit size depends on the amount of the forage to be stored.
3. Using chaff cutter, the forage to be preserved is chopped to lengths of about 1 inch long.

4. To prevent the forage contact with soil, a polythene sheet should be placed by covering the bottom of the pit and all sides of the pit.
5. The chopped forage should be placed into the pit and spreaded it into a thin layer and this process should be repeated until one third of pit is covered.
6. One litre of molasses is then diluted with three litres of water and it is sprinkled evenly on the forage to be preserved. Adding molasses to the forage is recommended since it is rich in sugar, which enables the bacteria to produce the organic acids immediately. More the molasses added, faster the acidification and preservation process occurred.
7. To prevent the forage from rotting, garden sprayer can be used to evenly distribute the molasses solution throughout silage pit and this will also help in feeding microorganisms to make the silage ferment quickly and saving the silage from rotting.
8. The forage should be pressed with feet to make the air out and protect from fungal attack. This should be done with caution as little air even cause the fungus and damage the forage.
9. More bags of chopped forage should be added after making the room (after pressing) with diluted molasses (as mentioned above). The process of adding forage with diluted molasses and pressing is repeated until the pit is filled in a doom shape.
10. The pit should be covered after final processing with polythene sheet on top to prevent from any water contact and a small trench around the sides of the pit is dug out.
11. Now the pit should be covered with soil to make the air out and the polythene should be prevented damage from rain, birds or any other animals.
12. The conservation through fermentation may take weeks. The pit is left until there is a shortage of fodder. The silage can last up to 2 years if it is prepared with well sheeting and good soil cover.
13. To use the silage, the pit should be opened from the lower side of the slope, the enough silage fodder for one day is taken and the pit should be closed again.





Opening the silage pit

It takes about 30 - 40 days for the silage to mature and be ready for feeding. The whole silage pit should never be opened at once. The narrow side should be opened a bit at one end. Enough material for each day's feeding should be removed and covered again. In this way, air is prevented from entering the silage. However, once the pit is opened, the silage should be used as quickly as possible.

Method of silage preparation

The specialized device or container used for preparation of silage is called silo. The silo are of:

Pile:

In this type of silo, there is no need of construction. Only a pile of chopped fodder is made on a ground and it is pressed with the help of tractor. This type of silo is recommended for short term preservation of fodder.



Long Silage Bag:

This type of silo consists of long stretchable bag. After proper filling and compaction, the end of bag is closed.



Silo tower:

These are long vertical silo of steel or concrete.



Silage Bunker:

It is most commonly used type of silo. This is rectangular structure which is open from one side or both sides. On both sides of walls of wood, steel, concrete are constructed. Dimensions of bunker depends upon the amount of fodder to be stored.



Temporary Bunker:

It consists of two frames of steel or iron which are covered by sheets of steel, iron or wood. The function of these frame is same as that of the wall of bunker but difference is that these are portable and can be easily transferred from one place to other place. Wherever fodder is to be preserved, these frames are fixed with the help of stands on both sides and space is filled with fodder. After compaction of fodder, these frames are removed and can be used somewhere else. Hay bales can also be used in place of frames for this purpose.



Silage Pit:

In this type of silo, a pit is constructed in ground. It may be rectangular or cylindrical.



Trench Silo:

This is compromised form of silage pit and bunker in which some fodder is preserved inside of pit and some outside of pit.

Baled Silage:

This is the most modern way of silage making in which fodder is preserved in the form of bale. Fodder is converted into bale via machine called silage baler and this bale is then tightly wrapped with polyethylene sheet with the help of wrapper. This bale can be easily transported.



Significance of silage for North East (in respect of dairy farming and green fodder unavailability in Rabi season)

Silage is an excellent energy feed for ruminant animals and is especially effective in optimizing milk yields from dairy cows. Silage preparation is one of the important methods for storage of green fodder for dairy animals which keeps all parts of fodder in appropriate condition for feeding than any other system of storage of fodder. It is necessary to adopt this method in North East India situation where drought or heavy rainfall or scarcity of fodder is frequent. Silage preparation is needed to preserve forage resources for the dry season or for winter in order to ensure continuous regular feed for livestock, either to sustain growth, fattening or milk production or to continue production in difficult periods when market prices are highest. Silage requires less space for storage as it is pressed in pit/tank than hay making. For daily cutting, transporting and chaffing of fodder in traditional way requires more labour and time but in case of silage, fodder cutting, transport, chaffing is done at one time only, so it is less labour and time consuming practice. Land under fodder cultivation is emptied and immediately it is used for plantation of other crops. So farmers' can take more crops in same land in a year against traditional way where land is reserved for fodder until all crops is harvested. Silage is prepared in closed and air tight condition so there is no danger of fire. Due to lactic acid in silage, it is easily digestible to animals, so energy required for digestion is used for other purposes like

milk production *etc.* Silage is tasty and flavoured, so it increases appetite of dairy animals. The importance behind to adopt silage is in scarcity to provide supply of fodder to dairy animals. Situations like drought, high rainfall and scarcity of fodder, farmers may use silage for feeding to dairy animals. (Rain fed area where shortage of green fodder is for March to June & in high rainy area or water logged lands, it is impossible to cultivate or harvest fodder). Due to treatment of additive for silage, farmers can supply energy, mineral & vitamins to dairy animals.

Quality maintain in silage

To maintain the quality of silage, the following points are necessary:

➤ **Preparing silo pit**

The size of silo pit should be decided on the basis of

- number of animals,
- body weight of animals,
- length of feeding period and
- amount of fodder available.

Silo pits should be easy to fill and easy to remove. It should be of adequate depth for better packing and less surface area to total mass exposed. It should be at highest spot to avoid water seepage. Walls should be strong. Boundaries should be raised so that rain water cannot enter silo pit.

➤ **Types of crops suitable for silage making**

Crops having good percentage of sugar and appropriate (35-40% dry matter; 65-60% moisture.) moisture are good for silage making.

➤ **Harvest at proper stage**

1. Crops at pre-flowering to flowering stage should be harvested.
2. Crops should not contain more than 75% moisture while silage making.
3. Crops with hollow stems such as maize should be chaffed to an inch size to prevent trapping of air and spoilage of silage.
4. High moisture crops can be dried in sunshine for 4 hours to reduce moisture content by 15%. Some dry hay or straw 5-20% can also be added.
5. If the crop is over ripe and too dry or it over dried, water is added during packing silo.

The following additives are added (any) when needed

Molasses: When legumes and low sugar grasses are ensiled, adding molasses improve quality of silage and its palatability. Molasses may be added at the rate of 3.5-4 % of green weight of silage.

Urea: Cereal forages can be enriched for nitrogen (protein) content by spraying urea at the rate of 0.5-1.0 % of fresh forage.

Lime: This can be added at a level of 0.5-1.0 % to maize silage to increase acid production.

Filling and sealing of the silo pit

1. The filling should be rapid with proper pressing by use of tractor after each filling to remove air.
2. Silo pit filling should be completed within 4-7 days.
3. After thorough pressing, top should be covered with polythene followed by soil layer of 6 inches depth.
4. Top of silo pit after filling and compressing should be higher than surrounding. All possible areas of air or water entry should be plugged.

Removing silage from pit

1. Silage should be ready within a period of 2-3 weeks of sealing.
2. Once opened, the pit should be fed completely.
3. Silage may be fed from top, layer by layer, daily.
4. On exposure to air for longer period, silage get spoiled. Hence, entry of air should be prevented.

Silage quality

Silage can be classified as good quality depending on its physical characteristics like taste, smell and colour but more precisely by measuring the pH in the pit. A pH of 3.5 - 4.2 indicates excellent fresh acidic/sweetish silage, 4.2 - 4.5 for good acidic, 4.5 - 5.0 fair less acidic and above 5.0 for poor pungent/rancid smelling silage. Good silage should be light greenish or greenish brown or golden in colour. It should have a pleasant smell like that of vinegar and acidic in taste and should not contain mould.

Black indicates poor silage. Overheated silage has the smell of burnt sugar and dry in texture. Badly fermented silage has offensive taste, strong smell, slimy soft texture when rubbed from the fibre or leaf.

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MECHANIZATION IN MAIZE CULTIVATION AND PROCESSING

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Mechanization is an important input for agricultural crop production and that has been neglected in the context of developing countries like India. Mechanization is defined as the art of using machineries to hasten production, accomplish task and reduce fatigue and human labour in order to produce better quality goods and services. Mechanization is useful and important as it takes place in almost every facet of human endeavour to meet required target and to boost efficiency. It speeds up the rate at which jobs are accomplished and are carried out in the nation's economy such as in banking, agriculture, building, construction, education etc. Mechanization increases the power supply to agriculture means that more tasks can be completed at the right time and greater areas can be farmed to produce greater quantities of crops while conserving natural resources. Applying new technologies that are environmentally friendly enables farmers to produce crops more efficiently by using less power.

Sustainable agricultural mechanization can also contribute significantly to the development of value chains and food systems as it has the potential to render postharvest, processing and marketing activities and functions more efficient, effective and environmentally friendly.

Sustainable mechanization can:

- increase land productivity by facilitating timeliness and quality of cultivation;
- support opportunities that relieve the burden of labour shortages and enable households to withstand shocks better;
- decrease the environmental footprint of agriculture when combined with adequate conservation agriculture practices; and
- reduce poverty and achieve food security while improving people's livelihoods.

Importance of Maize Crop

Maize is the most widely distributed crops of the world. It is cultivated in many parts of world at different altitude ranges from 500 m to 4000 m from sea level under rainfed, irrigated to semi-arid conditions. Duration of crop is available as regards to varieties maturing in 85 days to more than 200 days with variability in grain colour and texture etc. As regards to area and production maize ranks third in world production (380 MT from 120MH) following wheat (440

MT from 240 MH) and rice (420 MT from 140 MH). This represents 24% of the total cereal production as compared to 27 % for wheat and 25% for rice.

More than seventy countries (including 15 developed and 58 developing) produce maize having more than 1, 00,000 ha. Indonesia, Philippines, France, Rumania, Yugoslavia and countries of former USSR are the other major maize producing countries. Within India U.P., Bihar, Rajasthan, Madhya Pradesh and Punjab are the maize producing states and north eastern states has the high potential for producing maize crop in India.

Important Tools and Implements for Planting of Maize

Naveen Dibbler



Figure.1. Naveen Dibbler

This dibbler is used for dibbling bold seeds like maize, soybean or costly/scarce seeds in less area and for gap filling purpose. This dibbler consists of jaw type seed placement device, cell type metering mechanism, lever type power transmission system for roller and jaws and seed box with delivery system. After filling the desired seed to be sown in field, the worker should keep the dibbler at desired place and gently push the lever (front of dibbler) for opening the jaw so that seed may drop. The field capacity/field capacity of the dibbler is 150 m²/h. The implement can saved about 13% saving of labour cost of per unit of output with the dibbler as compared to traditional. It also avoids bending posture, which is generally adopted in traditional method. Line sowing is done with the equipment that promotes use of mechanical weeders thereby reducing drudgery and cost during weeding operation.

CIAE Seed Drill



Figure 2. CIAE seed drill

The device is used for row sowing seeds of wheat, soybean, maize, gram, pigeon pea etc. It consists of a handle, hopper for seed and fertilizer, peg type ground wheel, a roller with cells and a hook for pulling the drill. The metering roller is directly mounted on the ground wheel shaft. Field should be well prepared. It is operated by two workers, i.e. one for pulling and another for pushing and guiding. Rope is tied to hook provided in front of the seed drill for pulling. Output is 18 times faster than traditional practice. By the use of seed drill, bending posture which is generally adopted in traditional method can be avoided. Line sowing is done with the equipment that promotes use of mechanical weeders for weeding thereby reducing cost and drudgery during weeding operation. Seed saving is also achieved. Apart 87% saving in labour cost per unit of output. By the use of seed drill, bending posture which is generally adopted in traditional method can be avoided. Line sowing is done with the equipment that promotes use of mechanical weeders for weeding thereby reducing cost and drudgery during weeding operation.

PAU Seed Drill

The implement is used for row sowing seeds of wheat, soybean, maize, gram, pigeon pea etc. The PAU seed drill has been refined for women workers using anthropometric data. It consists of a handle, hopper for seed, a ground wheel, a fluted roller and a hook for pulling the drill. The metering of seed is done with fluted roller. It is operated from the ground wheel shaft

through chain and sprocket mechanism. The seed drill needs to be operated in well-prepared field. The seed drill is operated by two workers, i.e. one for pulling and another for pushing and guiding. Rope is tied to hook provided in front of the seed drill for pulling. The working capacity of the implement is 430 m²/h. Output is 18 times faster than traditional practice. By the use of seed drill, bending posture which is generally adopted in traditional method can be avoided. Line sowing is done with the equipment that promotes use of mechanical weeders for weeding thereby reducing cost and drudgery during weeding operation. Seed saving is also achieved.



Figure 3. PAU seed drill

Rotary Dibbler



Figure 4. Rotary dibbler

The rotary dibbler is used for dibbling bold or medium or costly/ scarce seeds in less area or gap filling of seeds in soybean, sorghum and maize crops. It is a manually operated push type equipment for dibbling bold and medium size seeds in rows at uniform spacing in well prepared soil. The field capacity of the rotary dibbler is 500 m²/h. It is suitable for dibbling bold seeds like maize, soybean and pigeon pea.

Implement for Weeding in Maize Plantation

Twin Wheel Hoe



Figure 5. Twin wheel hoe

Twin wheel hoe is use for weeding and interculture of row crops. The implement consists of two wheels, frame, V-blade fixed on a tyne, U-clamp and a handle. The cutting and uprooting of weeds in field is done through push and pull type action of the equipment. The equipment is operated at optimum soil moisture condition and preferably after 20-25 days of sowing i.e. when the weeds are small i.e. 1 to 3 cm height for better weeding performance. The field capacity of the twin wheel hoe is 150 m²/h. It can saved about 43 % labour cost per unit of output. It avoids bending/squatting postures, which is generally adopted with short handled hand hoe in traditional method. Productivity of worker increased more than three times with the equipment than traditional method.

Manual Power Weeder

Manual power weeder is the petrol based engine used for weeding as farm cultivator, it is very flexible and easy operation. It can finish tilling & cultivating. It is very good for weeding management. It can help farmers to save lots of labour and improve efficiency. The type of

engine is 2-stroke, single cylinder and it is air-cooled. The average power requirement for the engine is 1.4 KW. The average weight of the machine is about 15 kg. The field capacity of the manual power weeder is 750 m²/h.



Figure 6. Hand power weeder

Post-Harvest Implements and Machinery for Maize

Tubular Maize Sheller

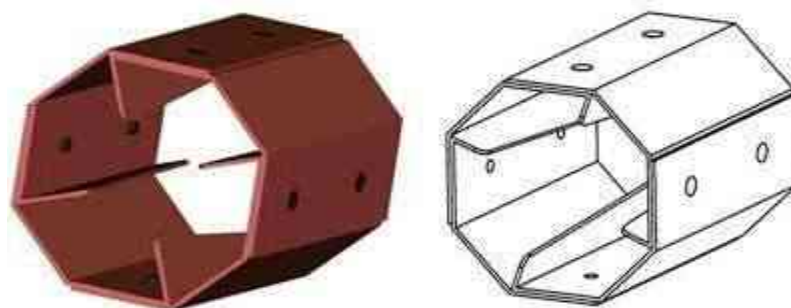


Figure 7. Tubular maize sheller

Tubular maize sheller is use for shelling maize from dehusked cob. It is made of mild steel sheet and is octagonal in shape. Four tapered fins are provided in the maize sheller, which helps in shelling the maize grain from dehusked cobs. A cob is inserted into it and by twisting action shelling is achieved. The working capacity of the tubular maize sheller is 27 kg/h and it can save about 15% of labour cost per unit of output in comparison to the traditional practice. The productivity of workers increased 1.6 times than traditional practice i.e. shelling with the help of sickle. The chances of injury to fingers are eliminated thus making the operation safer for workers.

Rotary Maize Sheller

Rotary maize sheller is manually operated equipment consisting of a frame, a flywheel, a hopper and three shelling gears. With one hand a person operates the equipment whereas cobs are fed by the other hand one by one. The shelled cobs come out through the port on other side. The working capacity of the machine is 73 kg/h. Output is very high and the equipment is suitable for farmers growing large quantity of maize. About 32% saving in labour cost per unit of output in comparison to the traditional practice. The chances of injury to fingers are eliminated thus making the operation safer for workers.

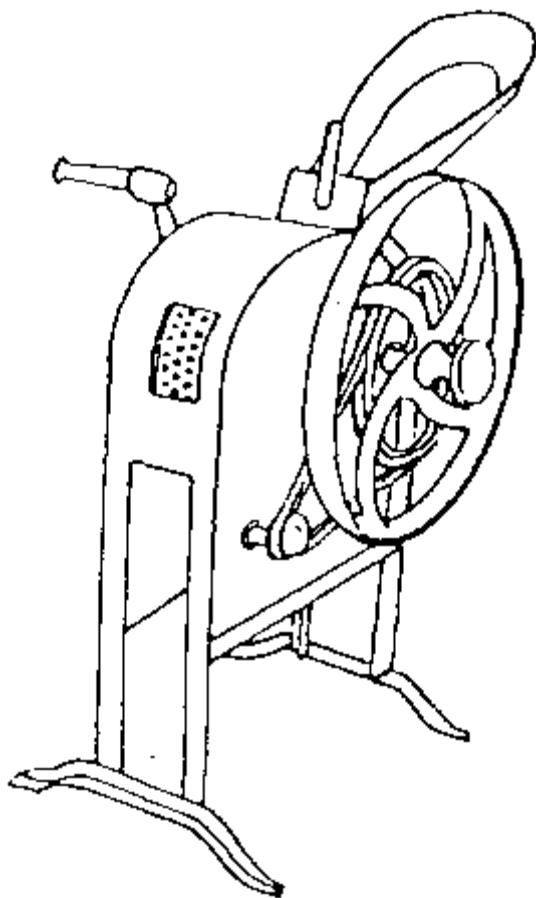


Figure 8. Rotary maize sheller

Storage and Storage Facilities of Maize

The success of any method of storage whether on an open shed floor under roof, outside under a sail, in a container or sophisticated concrete or steel silo equipped with air circulation fans depends on the moisture content of the maize, prevailing ambient temperature and level of humidity in the surrounding air. The grains are alive and although they go through a period of dormancy will start to germinate when re-wetted by rain or by absorbing moisture from the air

when the humidity is over 70%. It is quite a task for the smaller farmer in the high humidity areas to maintain grain in storage without spoilage due to fungus, other pathogenic organisms and insects. The biologically active grains respire during storage and produce heat and moisture. It is very important to be able to move and remix a crop by hand even when placed in bulk on a shed floor. Proper silos are designed with mechanised augers, continuous flow driers, elevators and fans to enable seed mixing and airflow management to bring the crop into the safe zones for long term storage.

Some of the Processed Product of Maize



Figure 9. Corn flour



Figure 10. Corn Flakes



Figure 11. Baby Corn Pickle



Figure 12. Corn Oil



Figure 13. Pop Corn



Figure 14. Corn Biscuit

Highly Mechanized Machinery for Maize

Maize Harvester



Figure 15. Maize Harvester

A corn harvester is a machine used on farms to harvest corn stripping the stalks about one foot from the ground shooting the stalks through the header to the ground. The corn is stripped from its stalk and then moves through the header to the intake conveyor belt. From there it goes up the conveying system through a fan system, separating the remaining stalks from the ears. The stalks blow out the fan duct into the field while the ears drop onto another conveyor belt. The ears ride the belt and drop into a large moving bucket.

Other equipments for value addition of maize

	
<p><u>Animal/Poultry Feed Processing Machine</u></p> <p>Power supply: Single Phase</p> <p>Power (W): 2.2kw</p> <p>Dimension (L*W*H):80*55*55cm</p> <p>Weight: 75 kg</p> <p>Working life: 6-8 years</p> <p>Capacity: 400 kg/h</p> <p>Price: Rs. 40,000/- (approx.)</p>	<p><u>Animal/Poultry Feed Pellet Machine</u></p> <p>Power supply: Three Phase</p> <p>Power (W): 7.5kw</p> <p>Dimension (L*W*H): 115*53*75cm</p> <p>Weight: 150 kg</p> <p>Pellet diameter: 3mm , or 4 mm, or 6mm</p> <p>Capacity: 400 kg/h</p> <p>Price: Rs. 80,000/- (approx.)</p>

	
<p align="center"><u>Maize Grit Puffs Nik Naks Snacks Extruder</u></p> <p>Capacity: 90-100 kg/h Price: Rs.150000/-</p>	<p align="center"><u>Puffed Corn Cheese Ball Making Machine/Puffed Snacks Processing Line</u></p> <p>Capacity: 100-120 kg/h Price: Rs.200000/-</p>
	
<p align="center"><u>Maize Grinding Mill</u></p> <p>Capacity: 270-450 Kg/h Price: Rs.2,25,000/-</p>	<p align="center"><u>Corn Degerminator</u></p> <p>Capacity: 125 Kg/h Price: Rs.2,00,000/-</p>

	
<p align="center"><u>Grain Cleaner cum Destoner</u></p> <p>Capacity: 15-17 Quintal/h Power Required: 5 hp Price: Rs.2,00,000/-</p>	<p align="center"><u>Hand Operated Maize Sheller</u></p> <p>Capacity: 15-17 Quintal/h Power Required: Human labour Price: Rs.12,000/-</p>
	
<p align="center"><u>Corn Thresher</u></p> <p>Power Required: 5 hp Capacity: 2000 Kg/h Price: Rs.4,00,000/-</p>	<p align="center"><u>Maize Harvester</u></p> <p>Capacity: 49 Ton/h Price: Rs.1,75,000/-</p>

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CLIMATE RESILIENT MAIZE PRODUCTION TECHNOLOGY FOR SIKKIM

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Impact of climate change on agricultural ecosystems has been a reality and threatens the food security in South Asia. Increase in temperature, higher CO₂ concentrations and abnormal patterns of precipitations coupled with higher frequency and intensity of drought and floods are likely to enhance considerably the climate risk to the major agricultural ecosystems. The United Nations Framework Convention on Climate Change (UNFCCC) described change of climate to be attributed directly or indirectly to human activities that alters the composition of global atmosphere and which in addition to natural climate variability observed over comparable time period. The change may be in the form of magnitude or variability of a single or multiple weather variables or weather phenomena. It is fact that climate and agriculture are linked to each other; both take place on a global scale. Rising temperature, erratic rainfall and declining in glaciers directly linked with the global warming which has a significant impact on agriculture. Similarly, the rising carbon dioxide levels across the globe have also both unfavorable and positive effect on crop yields. Around 52 per cent of the population in India is directly or indirectly depends on agriculture and allied activities either as farmers or agricultural laborers, and their concentration is higher at 76 per cent in the villages. It is the right time to say that the climate is sensitive for agriculture of our country, coupled with varied agro-climatic conditions, rich biodiversity and abundant natural resources, faces the daunting task of feeding 17.5 percent of the global population with only 2.4 per cent of land area and 4 per cent of the water resources at its disposal. Still, 60 per cent of agricultural production system of the country falls under rainfed farming covering almost 46 per cent of India's geographical area, generating 55 per cent of the country's agricultural output and feeding 40 per cent of the total population of the country (Planning Commission, 2012). Rise in temperature has a direct impact especially on the *Rabi* season crops and every 1⁰C rise will reduce wheat production by 4 to 5 million tones. It has been observed by the different researchers that a very small change in temperature and rainfall has put a significant effect on the quality as well as quantity of all these important cereals, pulses fruits, vegetables, and aromatic and medicinal plants.

The Northeastern Himalayan Region of India is also very vulnerable to the climate change due to topography, having prone to accelerate to different kind of erosion vis-à-vis the eastern Himalayan landscape and its trans-boundary river basins and its inherent socio-economic instabilities. The region falls under high rainfall zone with varied tundra to subtropical type of

climate. In the region continuous high rainfall during rainy seasons occurs. The agriculture scenario in North Eastern Region (NER) of India is passing through a transition phase due to slow but prominent pressure in climate change in one hand and increasing food demand on the other. The annual average rainfall of NEH region is estimated to be around 2450 mm. The water use efficiency of the region is also very low in spite of the availability of about 34% of country's total water wealth and 10 percent (42 M ha m) of country's total rain water resource (420 M ha M) in NE region. Most of the rain water goes waste by runoff resulting large scale soil erosion along the slope cultivation. Amidst the major production constraints of NEH region viz., poor soil fertility, low variable in rainfall, undulating topography, poor resource base, scattered land holdings and short growing seasons; the climate change add some impediments in terms of variability in occurrence, intensity and distribution of rainfall; runoff, soil erosion and floods due to excess and erratic rainfall during *kharif* and water deficit during crop sowing in *kharif/rabi* season which result in shifting in crop planning. In the absence of organized water resources and irrigation plan, the region is in threat for complete or partial crop loss.

Sikkim Himalayan agroecosystems are most vulnerable to climate change. Climate variability assessment has shown that there is a marked change in the climatic parameters all the districts of Sikkim in almost all the seasons (Rahman *et al.*, 2012, Das *et al.*, 2017). The variable rainfall and rising temperature over the years are the major factors placing their impact on the agriculture sector. The rainfall depriving situation has becoming serious over the years especially during *Rabi* months. Besides, Sikkim has major cropping area under rainfed agriculture.

Climate change: A concern in Sikkim

Climate change phenomenon is now a global reality as the global climate has already warmed by 0.74° C as compared to the beginning of the twentieth century. Moreover, it is projected that the mean global winter temperatures will be increased by as much as 3.2° C in 2050s and 4.5° C by 2080s and summer temperatures will be increased by 2.2° C in 2050s and 3.2° C by 2080s. If the current trend in global carbon emissions continues, temperatures will rise by about 1° C by the year 2030 and by 2° C by the next century. Global atmospheric concentrations of principal green house gases (carbon dioxide, methane, and nitrous oxide) have increased markedly as a result of human activities since 1750 and now far exceed pre-industrial values over the past 650,000 years. Global GHG emissions have grown since pre-industrial times with an increase of more than 70 per cent between 1970 and 2014. CO₂ has increased from a pre-industrial value of about 280 ppm to 379 ppm in 2005. The scientific assessment report of IPCC-2013 showed between 1880 and 2012, global average temperature increased by 0.85°C wherein warming was faster in the last 50 years at the rate of 0.13°C per decade almost twice the per decade rate for the last 100 years. Global average sea level has risen at an average rate of 1.8 mm per year with the rate being faster, (about more than 3) during the last few years. Further it is projected that 2°C increase in average temperatures would reduce world GDP by approximately 1% and as per the World Development Report (2010) of

World Bank for every 2⁰C rise in temperature due to climate change, the agriculture GDP of India will reduce by 5 percent. India is projected to face the consequence of instability in food grain production due to reductions of agricultural output by 30% or more. It is predicted that as a result of large scale climatic aberrations the mean temperature in India would increase by 0.2–0.4⁰ C in *kharif* and 0.5–0.8⁰ C during rabi by 2020s and by 0.4–2.0⁰ C during kharif and to 1.1–4.5⁰ C in rabi by 2070s.

Hilly region is more vulnerable to climate change than any other place. Past studies on climate change in hills have suggested significant warming in higher elevations leading to reduction in snow and ice coverage with increased frequency of extreme events like landslides and droughts. The impact of climate change can be much greater for indigenous communities living in the more remote and ecologically fragile zones and relying directly on their immediate environments for subsistence and livelihood (UNFCCC 2004). Like in other developing countries, there is a lack of spatially disaggregated meteorological records. In the state, long term, consistent data is available only for one station - Gangtok. Climate change related studies based on the analysis of the data for this station month-wise, season wise and annually from 1957 to 2014 indicates a trend towards warmer nights and cooler days, with increased rainfall except in winter. The maximum temperature in Gangtok has been rising at the rate of 0.2⁰C per decade and the annual rainfall is increasing at the rate of nearly 50 mm per decade. Comparison of long term meteorological data available for Gangtok station (1957 to 2014) with the trend over the last few years (2006-14), shows an acceleration of these patterns, with winters becoming increasingly warmer and drier now. Continuous rainfall in the wet period has caused large and small landslides resulting in loss of fertile land, forest and human properties. Winter drought of past few years has significant impact on the farming system and livelihood of these areas. Long winter droughts have made the life more difficult. Increased number of forest fires has been reported in recent years due to long droughts causing loss of biodiversity and human resources. Increased temperature, landslides, droughts and decreased snow cover have become threats to the rich natural diversity. Main findings of the vulnerability assessment conducted different organizations working on climate change in Sikkim are as follows

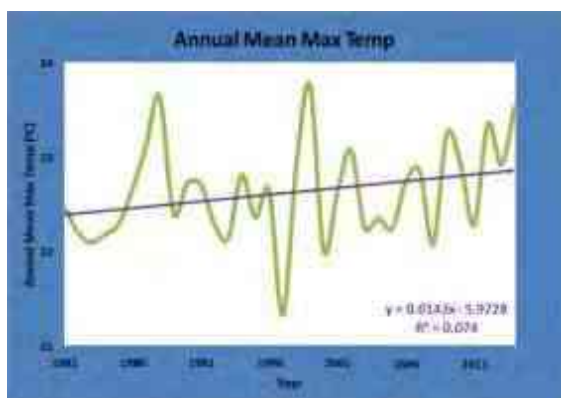


Fig. 1 Trends in annual mean maximum temperature

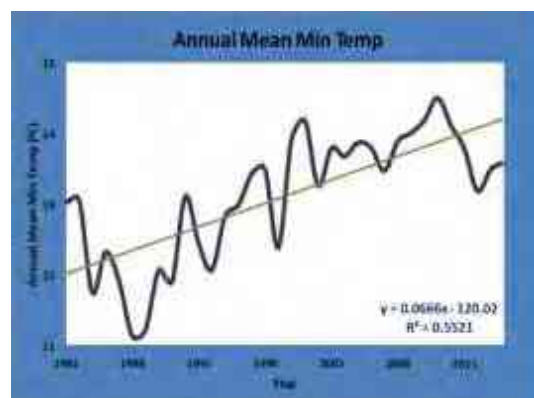
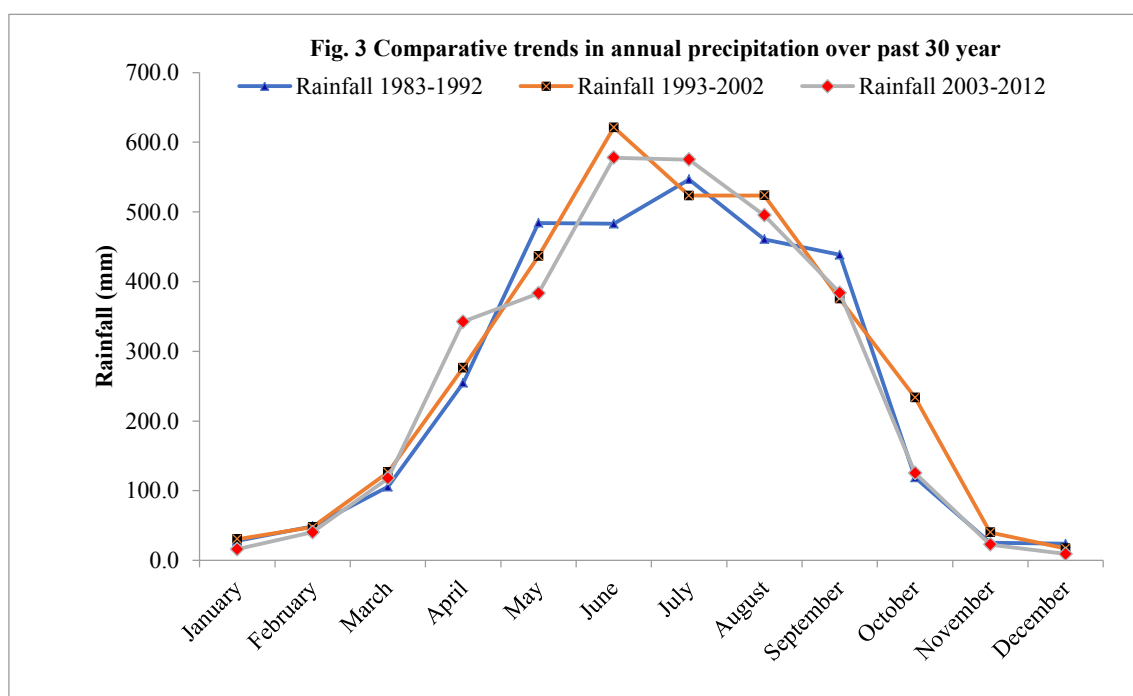


Fig. 2 Trends in annual mean minimum temperature

Temperature will go up by about 1.7°C in almost all the districts of the North Eastern Region. In North and South Sikkim districts temperature will even rise by more than 2°C.

Rainfall pattern depicted in Fig. 3 showed that in Sikkim mean rainfall of decennial (1993-2002) has been recorded 7.21 and 5.02 per cent higher rainfall than 1983-1992 and 2003-2012, respectively. Similarly, the pattern of distribution of rainfall was also even throughout the year. Winter season also experienced enough quantity of rainfall in the same decennial. Contrary to that 1983-1992 and 2003-2012 experienced less rainfall. It is projected that rainfall may decrease by over 5% in future and erratic pattern may be seen due to the change climate.

- ❖ With an increase of 26% the frequency of annual **extreme weather events** with respect to rainfall (*i.e.* frequency of days with either very high or very low rainfall) is projected to rise significantly in the North Eastern Region. Possible impacts can be flash floods and landslides on the one hand and water shortages and crop failure on the other.



Changing climate creates problems and direct impacts have been seen on the socio-economic development of a society. The frequency, magnitude and duration of damaging climate conditions are changing. It is now widely understood that efforts to address the impacts of adverse climatic conditions on human development must be undertaken within the context of a longer term vision of development. Agriculture, forestry and fisheries are sensitive to climate change impacts on the one hand, and are also contributing to emissions on the other. Agriculture accounts for 13.5 percent of global greenhouse gas emissions from fertilized soils, enteric fermentation, biomass burning, rice production as well as manure and fertilizer production.

Maize production under changing climatic scenario in Sikkim

According to Intergovernmental Panel on Climate Change (IPCC) mitigation is defined as “an anthropogenic intervention to reduce the sources or enhancement of the greenhouse gases”. On other hand climate adaptation refers to the ability of a system to adjust to climate change, including climate variability and extremes, to moderate potential damages, to take advantage of opportunities or to cope with the consequences. Some of the climate adaptation resources conserving technologies have been tested at ICAR Sikkim Centre which is as follows.

Maize is one of the important pre-*Kharif* crops in the region. Farmers of the state leave their land fallow during the *Rabi* season due to negligible and very less rainfall, which is not able to support crop cultivation. Therefore, maize-fallow and rice-fallow are the predominant cropping sequence in the rainfed and irrigated region of Sikkim Himalayas, respectively resulting in very low cropping intensity (about 118%). The options are very much limited to increase in the crop intensity and productivity due to rainfed drier winter particularly for Sikkim. Some of the important measures to enhance the CI in the state are as

- Short duration efficient crop varieties are required to enhance the cropping intensity in rainfed areas.
- Inclusion of legumes in conservation agriculture for diversification of cereal based cropping systems will help to overcome the problem of declining factor productivity.
- Adoption of no-till practice will also help in timely seeding of either of the crops in system mode, and hence, lead to increase in productivity of maize-based cropping system.

Diversification/Intensification of Maize-Based System under changing climate

Climate change may also have negative penalties for agricultural production in fragile Himalayan ecosystem; hence there is a need to build resilience into agricultural systems. Implementation of increased crop diversification may be the rational and cost-effective method to cope with climate change. Crop diversification can improve resilience in a variety of ways: by suppressing pest outbreaks and dulling pathogen transmission and by improving soil fertility and input use efficiency. Crop diversification may enhance the ecosystem services and climate resilience, which reduces production risk under aberrant weather condition. In Sikkim among the cultivated crops, maize covers maximum area (40,000 ha) and is sown in the *pre-kharif* season starting from February to mid-March. Most of the areas (about 60-70%) after maize harvest lying vacant only in some pockets farmers are grown black gram and rice bean. Even after harvesting of maize heavy rainfall hampers the sowing of pulses due to water logged and higher moisture in soil at the time of sowing and moisture scarcity in latter phase of crop growth. So it may not be possible plough the field for sowing of next crop during the season. Hence, ICAR-NOFRI (formerly ICAR Sikkim Centre) has developed no-till technology for the cultivation of

second and third crops in diversified cropping systems. For rainfed and irrigated areas of Sikkim the following cropping systems have been tested and found suitable under changing climatic scenario.

For irrigated areas

- Maize+beans-vegetable pea
- Maize-*Pahenlo dal*-cole crops
- Maize-*Pahenlo dal*-coriander
- Maize (green cobs)-*Pahenlo dal*-fenugreek (leafy vegetable)
- Maize-French bean-vegetables (cauliflower/broccoli/cabbage/Spinach)
- Maize (green cobs)-rice-vegetable pea/coriander/fenugreek (leaves)
- Maize-*Pahenlo dal*-leafy mustard

For rainfed areas

- Maize (green cobs)-*Pahenlo dal*-buckwheat/toria
- Maize+beans-vegetable pea
- Maize+beans-rajmash
- Maize+beans-buckwheat
- Maize-black gram/green gram/French bean

Diversification of maize- based cropping system through inclusion of pulses:

Inclusion of short duration pulses like black gram, rajmash and pea may be the options for enhancing the cropping intensity up to 200 per cent in the state. ICAR Sikkim centre identified maize – black gram, maize + bean – rajmash and maize + bean – pea in those area where irrigation facilities are not available.



Diversification through no-till black gram (Pahenlo dal) and rajmash

No-till and or reduce tillage technology makes cultivation more farmer friendly and saves time and input as well as produces healthy crops. Hence, to reduce the labour cost and time for preparation of land form sowing after harvest of maize, ICAR Sikkim developed no-till techniques for sowing of black gram and rajmash immediately after



harvesting of maize. After harvesting of maize field should be cleaned by removing all the derbies remained on surface. FYM or mixed compost @ 5 t/ha should be applied as basal application prior to sowing followed by goat manure/poultry manure @ 1-2 t/ha as basal dose to overcome micronutrient deficiencies. Before sowing, seed should be treated with *Rhizobium* and PSB @ 200 g/kg seed. Around 20-25 kg seed is required for a hectare of land for black gram and 75-80 kg/ha required for sowing of rajmash. Sowing should be done by opening a narrow slit (5-8 cm depth) for placement of seed at 30-40 cm row to row and 10-15 cm plant to plant distance. Two hand weeding is required one at 15-20 DAS and second weeding at 30-40 DAS. The results of the study recorded rajmash grain yield (1.37 t/ha) which was 17.8 per cent higher in no-till practice over CT. Similarly, the black gram yield was also higher under NT planting (0.98 t/ha) over CT.

In-situ moisture conservation strategies for diversification

Diversification of maize based cropping system through *In-situ* moisture conservation practices seems to be the only way to enhance the productivity and sustainability in the state. In order to meet the demand of pulses in the state, short duration pulse crop rajmash (*Phaseolus vulgaris* L.) variety which will fit in maize-fallow under rainfed condition is demanded by the farmers in the state. Short duration rajmash variety can escapes the drought during early winter season may enhance the cropping intensity after harvest of maize crop in the state. Keeping these points in view, ICAR-NOFRI Sikkim initiated research strategies for growing pulses in *rabi* season by using locally available biomass and 30 per cent maize stover as a mulch for conservation of soil moisture. At the end of September month is suited for sowing of rajmash after maize. A good seed bed should consist of 5 to 7 cm of fine firm soil that is free from weeds. Apply vermicompost @ 2.0 t/ha + neem cake @ 1.0 t/ha + FYM @ 5.0 t/ha in furrows open for sowing of the seeds. VL Rajma-63, VL Rajma-125, IPR 98-5 (Utkarsh), HUR-15, HUR-137 and SKR-57 is suitable for cultivation in Sikkim. Seed should be inoculated with *Rhizobium* culture @ 20 g/kg seed and seed rate is 100-125 kg/ha. Sowing should be done in furrows at a spacing of 30 cm x 10 cm with 3-5 cm depth. Two hand weeding, first at 15-20 DAS and second at 40-45 DAS should be done to get the optimum yield. Spraying of Spinosad 45 SC @ 0.3 ml/l and second spraying at 20 days interval is effective to control gram pod borer and legume pod borer. Harvesting should be starts at 90 -95 days after sowing. In the study, Raj-2 recorded significantly higher grain yield (1.73 t/ha) over Raj-1, SKR-57 and Tripura Raj Sel-1 but remained at par with Raj-3 and Raj-4.



Promotion of technologies that enhance biological N-fixation and improve nutrient use efficiency

There are several reasons for low productivity of different crops in the region out of which proper nutrition is of paramount importance. Hence, alternative methods *viz.*, use of certain specific inoculums on important crops is the need of the hour. Therefore, different methods of inoculation (control, cow urine *Azospirillum* spp., *Azotobacter* spp., *Azotobacter* spp. + *Azospirillum* spp. and *Azotobacter* spp. + *Azospirillum* spp. + cow urine) has been tested at the research farm of ICAR Sikkim. Among the different inoculations, combined application of *Azotobacter* and *Azospirillum* was found most efficient and resulted in maximum values of yield attributing characteristics (seeds/plants, seed yield/plant and test weight) and grain yield of maize.

Resource conservation techniques for intensified maize-based cropping systems under organic farming

ICAR–National Organic Farming Research Institute (Formerly ICAR Sikkim Centre) assessed the various combinations resource conservation techniques in intensified maize-based cropping system under rainfed conditions. Among the tested practices of land configurations, ridge top sowing along with earthing up at knee-high stage is recommended for pre-*kharif* season maize. Similarly, no-till sowing of all the Rabi season crops has been advocated for reducing production cost and energy use except for buckwheat cultivation, for buckwheat reduced tillage is recommended for better soil-seed contact, which ensure proper plant stand and yield. Plenty of biomass is available in Sikkim which can be used as mulch material for *Rabi* season crops. Hence, *In-situ* moisture conservation through residue retention, field litter and other available biomass has been recommended for taking the second crop during post rainy season. Similarly the several short duration varieties and crops has been evaluated for accommodating number of crops at a given place and time for enhancing system profitability.

Effect of nutrients management and moisture conservation practices on efficiency of intensified cropping systems

All the intensified cropping systems (maize-urd bean (*pahenlo dal*)-buckwheat and maize-urd bean (*pahenlo dal*)-mustard) recorded higher production efficiencies over maize-fallow system. Among the diversified/intensified systems, maximum system production efficiency (28.34 kg/ha/day) was recorded with maize-*Pahenlo dal* (green seeded urd bean)-buckwheat. Similarly, relative production efficiency (RPE) *i.e.*, the capacity of the system for production in relation to existing system was maximum (190.4%) with maize-green seeded urd bean-buckwheat system followed by maize-urd bean-toria sequence. With regard to apparent water use productivity (AWUP) and water requirement (l) per kg of maize grain equivalent, maize-urd bean-buckwheat system showed its superiority over the others and resulted in the lowest amount of water requirement for kg grain production (296 liter of water/kg of maize grain

equivalent yield). Among the organic sources of nutrients, applied to diverse cropping systems (maize-fallow, maize-urd bean (pahlenlo dal)-buckwheat and maize-urd bean (pahlenlo dal)-mustard) substitution of organic nutrients in 25% FYM + 25% MC + 25% VC + 25% PM+BF in combination resulted in maximum system production efficiency (23.89 kg/ha/day), relative production efficiency (30%), average water use productivity (287.8 kg/ha-cm) and required the least amount of water per kg grain production of maize (443 litre of water for kg grain production) in system mode. During winter season, moisture conservation by mulching resulted in higher system production efficiency, AWUP (265 kg/ha-cm) and required lower amount of water for kg grain production as compared to no mulching.

Table: 1 System production efficiency (SPE), relative production efficiency (RPE), apparent water use productivity (AWUP) and water equivalent of maize grain under diverse cropping system, nutrient and moisture management practices

Treatment	SPE (kg/ha/day)	RPE (%)	AWUP (kg/ha- cm)	Water (l/kg) equivalent of maize grain
<i>Cropping systems</i>				
Maize-fallow	9.76	00	117.6	859.4
Maize-urd bean –buckwheat	28.34	190.4	341.4	296.0
Maize-urd bean- toria	27.20	178.7	327.6	308.5
SEm±	0.09	--	1.1	2.1
LSD (<i>P</i> =0.05)	0.27	--	3.3	6.2
<i>Organic N sources substitution</i>				
Farmers Practice	18.37	00	221.3	573.5
50% FYM+25%MC+25%VC+BF	22.08	20.1	265.9	474.5
50%MC+25%FYM+25%VC+BF	22.73	23.7	273.8	460.5
25%FYM+25%MC+25%VC+25%PM+BF	23.89	30.0	287.8	443.3
SEm±	0.08	--	0.9	2.5
LSD (<i>P</i> =0.05)	0.19	--	2.3	6.2
<i>Moisture conservation practices</i>				
Without mulching	21.53	--	259.4	490.5
With mulching	22.00	---	265.0	485.4
SEm±	0.04	--	0.4	0.5
LSD (<i>P</i> =0.05)	0.09	--	1.0	1.1

System productivity, production and land use efficiency of the intensified system

Intensified cropping systems were found more productive over the ruling farmer's practices (maize–fallow) of the state. While comparing the total productivity of intensified cropping systems in terms of maize grain equivalent yield, significantly higher maize grain equivalent yield (MEY) and system production efficiency (24.36 kg/ha/day) were recorded with more intensified cropping system {maize (green cobs)–urdbean–buckwheat} followed by maize–rajmash and maize–toria system (Babu *et al.*, 2016), whereas the lowest was recorded when the field was left fallow in consequent years after maize harvesting. Similarly, relative production efficiency (RPE) *i.e.*, the capacity of the system for production in relation to existing system was maximum (169.39%) with maize (green cobs)–urdbean–buckwheat system followed by maize–rajmash sequence. Land use efficiency (LUE) which refers to the utilization of land in temporal dimension for cropping activity was recorded to be higher for the maize (green cobs)–urdbean–buckwheat system followed by maize–rajmash. This was due to higher crop duration which in turn recorded the highest LUE and efficient utilization of land over other systems. But the lowest LUE was recorded in maize–fallow system as the land was utilized very poorly in this system (Babu *et al.*, 2016).

Economics and employment generation efficiencies of improved cropping systems as compared to maize-fallow

Economic analysis showed that the highest net return (303.4×10^3 Rs./ha) and B:C ratio (2.59) was significantly higher with maize (green cobs)–urdbean–buckwheat system followed by maize–rajmash cropping system. On the other hand, the lowest return and B:C ratio was recorded in maize–fallow cropping system. With regard to relative economic efficiency (REE) *i.e.*, comparative measure of economic gains over the existing system, all the intensified systems had higher economic gain over the maize–fallow system. Similarly, the maximum system profitability (831.2 Rs./ha/day) was recorded with maize (green cobs)–urdbean–buckwheat. On the contrary, minimum system profitability (238.4 Rs./ha/days) was recorded with maize-fallow system (Babu *et al.*, 2016).

Babu *et al.* (2016) reported that intensification of the system adds to the employment generation and generated more employment as compared to maize–fallow cropping system, which generated only 106 man–days/ha to harvest the final produce. Data related to relative system employment generation efficiency (REGE) *i.e.*, additional man days required for a diversified system in relation to the existing system, showed that all the intensified systems had higher economic generation ability as compared to the prevailing system of the region. Among the cropping sequences, cultivation of maize (green cobs) –urdbean–buckwheat resulted in maximum REE (168.9%) followed by maize–rajmash system.

Energy analysis of intensified system

A system is considered more efficient when it produces higher output energy and requires less input energy. Various intensified cropping systems required different levels of total energy inputs (Babu *et al.*, 2016). Concerning the energy output, there were significant differences between the intensified systems. Among the various cropping systems, maize (green cobs)–urdbean–buckwheat recorded the highest gross energy output (374.5 GJ/ha) followed by maize–rajmash cropping system (252.5 GJ/ha). Similarly, maize (green cobs) –urdbean–buckwheat cropping system recorded the highest net return of energy (359.1 GJ/ha) followed by maize–rajmash cropping system. However, the least return of net energy (122.9 GJ/ha) was recorded with maize–fallow system. Among the maize–based systems under study, significantly higher energy use efficiency (24.5%) *i.e.*, the ratio of energy output to energy input was recorded with maize (green cobs)–urdbean–buckwheat cropping system followed by maize–buckwheat cropping system. However, maize–fallow system resulted in lowest energy use efficiency. Correspondingly, the energy productivity *i.e.*, kg of grain produced per unit of energy invested was higher under maize (green cobs)–urdbean–buckwheat cropping system and least with maize–rajmash cropping system.

Conclusion

Climate change poses serious threat not only to country's ambitious poverty reduction goals but also to the regional level specifically to Sikkim. Therefore, it is necessary to adopt resource conservation techniques especially conservation agriculture practices for enhancing productivity and resource efficiency which could also be mitigation and adaptive strategies to combat climate change. Diversification/Intensification of maize based system along with intelligent crop management practices under both irrigated and rainfed ecosystems of Sikkim Himalayas may enhance the profitability and resource use efficiency. Therefore, diversification of mono cropped maize area is highly recommended for enhancing the profitability and productivity of organic agriculture, which may sustain the livelihood security of organic growers in Sikkim.

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**CLIMATE RESILIENT TECHNOLOGIES FOR SUSTAINABLE MAIZE
PRODUCTION IN MANIPUR**

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Maize known as Queen of Cereals, also called corn is one of the most important cereal crops of the world. Maize (*Zea mays* L.) is the third important cereal crop in the world after wheat and rice with respect to area and production. India is the fifth largest producer of maize in the world, contributing 3% of the global production, though productivity is much lower (2.60 t ha⁻¹) than global productivity (5.6 t ha⁻¹) and other potential maize growing countries like USA (12.08 t ha⁻¹), Canada (10.33 t ha⁻¹), Australia (8.3 t ha⁻¹), Argentina (8.20 t ha⁻¹) and China (6.55 t ha⁻¹) (FAOSTAT, 2016). In the North Eastern Himalayan Region (NEHR) of India, maize is the second most important crop, next to rice and is mostly grown under rainfed hilly upland 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. The average productivity of maize in the region is very low (<1.5 t ha⁻¹). In NEHR of Manipur, area under maize cultivation is 26,090 ha with production 58,610 Mt with a productivity of 2.25 Mt/ha (DoA, 2013-14).

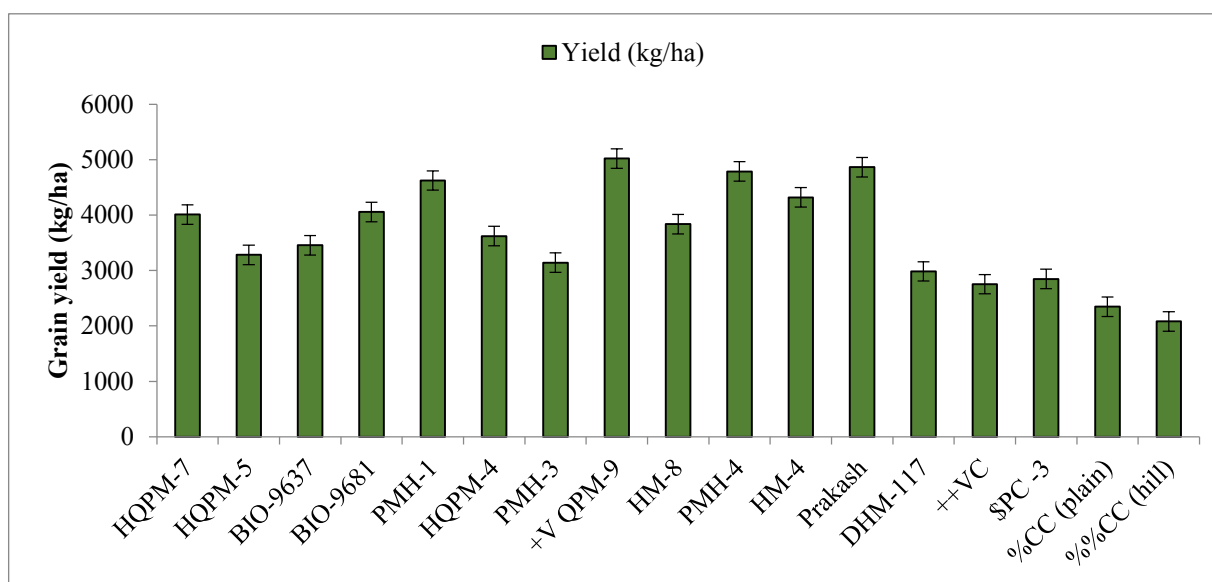
In the North Eastern Himalayan Region (NEHR), maize production plays a significant role in ensuring food security and is used both for direct consumption and as well as for second cycle produce in piggery and poultry farming. In NEHR, most of the area is comprised with Terrace and sloppy lands, where, land productivity and resource use efficiency (Water and nutrient productivity; other resources and energy efficiency) is very less. The diverse and complex North Eastern Himalayan Region (NEHR) climate allows for rainfed cropping, which differed in crop phenology from other part of the country. With the increasing evidence of less seasonal rainfall, terminal heat, frequent occurrence of extreme weather events coupled with intensive rainfall pattern across the region, the resource use efficiency vs. productivity can be analyzed utmost. However, successful maize production depends on the appropriate technology and accurate application of production inputs that will sustain the environment as well as agricultural production. The success and level of profit from maize depend on the choice of technologies to be adopted (Ansari et al., 2016; 2017). Spatial and temporal management practices are capable to produce 2 to 3 times more yields with better management practices over farmers practice.

Current and future importance of genotypic performance evaluation in hill agriculture

Climate is a very decisive factor for the adaptation of various genotypes. Temperature variation, cloudy weathers, variation in rainfall is directly related to radiation use efficiency. Response of plants to biotic and abiotic stresses is also reflected in change in their photosynthetic rates (Conocono et al. 1998, Kumar 2000). Sharma and Singh (1994) and Kumar P (2002) reported a wide variation in photosynthesis rate and productivity among the genotypes. However, study on phenology behaviour and productivity, radiation use efficiency of maize genotypes in relation to diverse and complex climate under hill agriculture is very important (Kumar 2002). It has been generally accepted, that the two to five fold increase in yields of many crops during the last 50 years has been brought about by (1) new high yielding varieties and (2) the input and crop management. Applying growth analysis as developed in the 1920's, principles have been described on solar energy absorption and fixation by crop canopies. The researches express the importance of leaf area index, spatial distribution of leaves, leaf duration, dry matter production per unit area and its relation with radiation use efficiency. Farmers want higher grain yields but also good stover yield. Furthermore, it is possible only higher conversion rate from source to sink with effective radiation utilization in responsive genotypes. Therefore, genotype selection for advancement in these traits will not be acceptable without consideration of primary traits such as better and efficient in utilization of solar radiation, productivity and stover yield also. The current work investigated opportunities for optimizing whole plant utilization, since the maize crop supports a wide range of needs such as for food-feed-fodder-biofuel (Klopfenstein et al. 2012).

Suitable maize genotype for Manipur

Ansari et al. (2016) studied the performance of maize genotype in Manipur during 2012-2013. They have reported that the mean maize grain yield varied from 2081 kg ha⁻¹ to as high as 5022 kg ha⁻¹. They have also found that the Vivek QPM-9 followed by Prakash recorded the highest grain yield while Chakhaochujak (hill) recorded the lowest grain yield. Similar to grain yield, oil and starch yields were also maximum in Vivek QPM-9 followed by Prakash while protein yield was maximum in HM-4 and Prakash followed by Vivek QPM-9. The minimum grain yield, oil yield, protein yield and starch yield was found in Chakhaochujak (hill), Chakhaochujak (plain) and Vijay composite.



Vertical bar represents significant level at 5%. +V QPM-9= Vivek QPM-9; ++VC= Vijay composite; \$PC -3= Pusa composite-3; %%CC (plain)= Chakhaochujak (plain), %%CC (hill)= Chakhaochujak (hill)

Similarly they Ansari et al., (2017) reported that the temperature plays important role in production. They recorded the highest and significant ($p < 0.05$) HUE was in Prakash followed by Vivek QPM-9 in. The lowest HUE was found in Chakhaochujak (hill). Temperature influences plant growth and development including emergence, flowering and maturity (Iannucci et al. 2008; Liu et al., 2010a, 2010b). The maximum heat units in the long duration genotypes were largely due to the longer duration of the reproductive phase. The heat units required for seedling emergence were almost same at different sowing dates. The duration from seedling emergence to maturity increased conspicuously and therefore, the heat units showed a marked increase under the higher duration genotypes.. The heat use efficiency is the proportion of grain yield and GDD. With the increase in GDD, the grain yield should also increase for maximization of economical harvest. Increase in HUE enhanced the maximum utilization of solar radiation across maize genotypes (Canavar et al., 2010, Ansari et al., 2017). Further, heat use efficiency is positively and significantly correlated with LAD in 2012.

Cropping system and Crop diversification

The most remunerative and tolerant maize genotype to intermittent moisture and soil acidity induced abiotic stresses can be a valuable alternative crop for replacing rice mixed farming from upland and medium land as well as shifting cultivated areas. Where, productivity of rice in the region is very low (0.5 to 0.9 ha^{-1}) and less economical. Therefore, adoption of improved maize production technologies may improve the productivity in the region.

Monocropping is the prevalent practice in Manipur. Therefore, crop intensification either horizontal or vertical will be most appropriate options to enhance the productivity of maize for ensuring food security.

There are some promising options for horizontal intensification of maize based cropping systems introduced by ICAR Manipur Centre in various hill districts of Manipur under conservation agriculture

Maize-Pea

Maize- Rapeseed and mustard

Maize- Lentil

Maize – Lathyrus

Maize-Vegetables

Maize-Beans

In intercropping, the crops are arranged in definite rows. Sowing of both crops may be done simultaneously or in staggered manner. Similarly harvesting time may also differ. Intercropping is an improved system of mixed cropping which ensures desired plant stand, ease in cultural operation, spraying of chemicals and harvesting, and higher returns. The major considerations for intercropping are the contrasting maturities, growth rhythm, height and rooting pattern and variable insect pest and disease associated with component crops so that these complement each other rather than compete for the resources and guard against weather adversities. Growing of crops in intercropping systems is found more productive particularly under rainfed conditions. More than 70% area of pulses in India is covered under intercropping systems. Pulses are intercropped with oilseeds, cereals, coarse grains and commercial crops. Pigeonpea is also inter/mixed cropped with short growing grain legumes.

Intercropping of pulses with cereals will more successful in terrace and jhum cultivated areas, where least possibility of water stagnation. Ansari and Rana (2012a) reported that the intercropping system recorded significantly higher as compared to sole cropping. It was due to almost similar yield of intercropped as that of its sole stand and additional yield of intercrop as a bonus in intercropping system. Similarly, intercropping system recorded the higher nutrient use efficiency and moisture-use-efficiency and economics as compared to the sole cropping (Ansari *et al.* 2011; 2012b; 2017).

Intercropping of pulses with maize is more popular in terrace cultivation and mixed cropping of pulses with rice/maize is more popular in jhum cultivated areas of Manipur. Maize + rice bean, Maize + soybean, Maize + Urdbean/Mungbean and are more remunerative in Kharif season. Perennial pigeonpea in intercropping system is generally grown on bunds with cereals, oilseeds and pulses. In Rabi season, mustard + Lentil/Lathyrus/pea, Makhyatmubi + vegetables, Broadbean + vegetables will more remunerative intercropping system (Ansari *et al.*, 2017b).

Technological interventions by ICAR Manipur Centre

ICAR Manipur Centre demonstrated the technologies in Participatory mode under collaborative programme of ICAR- Indian Institute of Maize Research, PAU Campus, Ludhiana under “Promoting improved technology of maize production in NEH Region”.

Maize based cropping system: We have introduced the maize based cropping system with the inclusion of oilseeds and pulses as sequential crops under Promoting improved technology of maize production in NEH region. The high quality protein maize cultivars (HQPM-1 and HQPM-5) demonstrated across the Manipur state in more than 400 ha area during 2015-16 to 2017-18 under collaborative project of ICAR- Indian Institute of Maize Research, New Delhi. The HQPM yield varied from 3.4 to 4.2 t/ha, which was twofold higher than local cultivar (Chaochujak).

Maize based intercropping system: Nine maize based intercropping systems were demonstrated in five districts viz. Chandel, Churachandpur, Imphal West, Ukhrul and Tamenglong districts of Manipur under the collaborative programme on Promoting improved technology of maize production in NEH region. Altogether 65 hectare area was covered for demonstration from the said districts. The on an average maximum maize equivalent yield was found in Maize + groundnut (R) (6.33 t/ha) followed by Maize + Soybean (A) than Maize sole cropping (3.4 t/ha). Maize + Groundnut (A), Maize + Greengram (A), Maize +



Participatory demonstrated Maize based cropping system in hill districts of Manipur

Urdbean (A), Maize + Rajma (R), and Maize + Ricebean (R) were fetched higher economic returns as compared to sole cropping of maize.

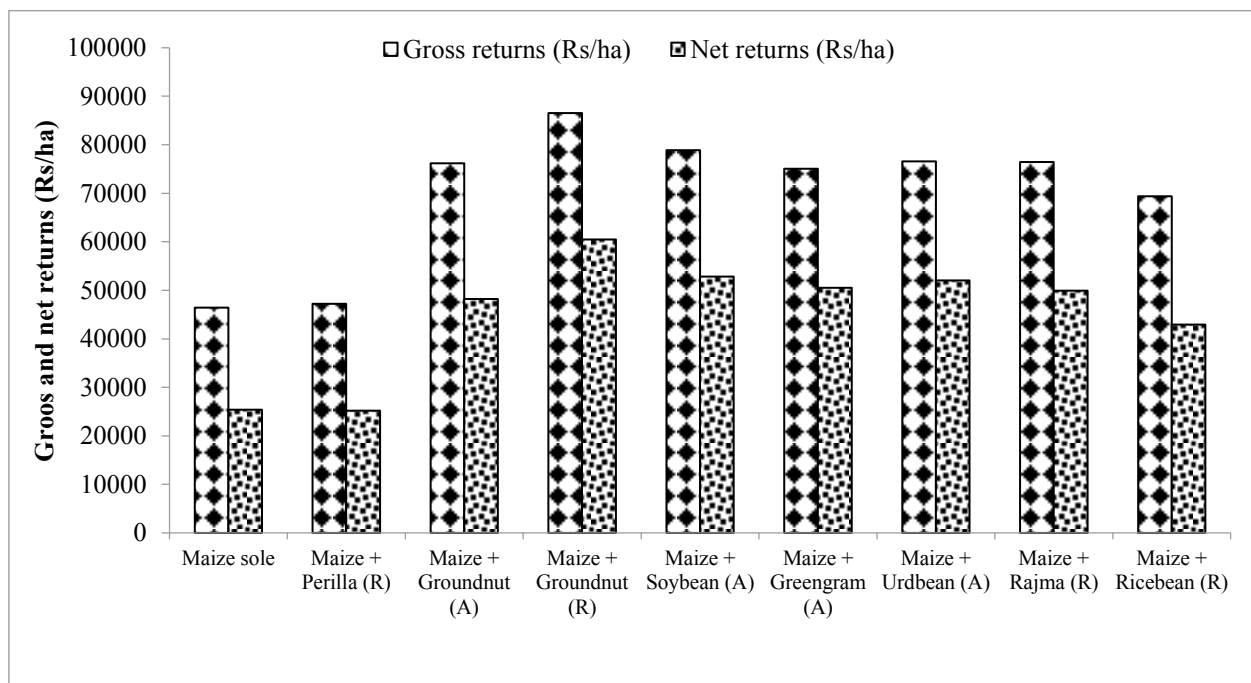
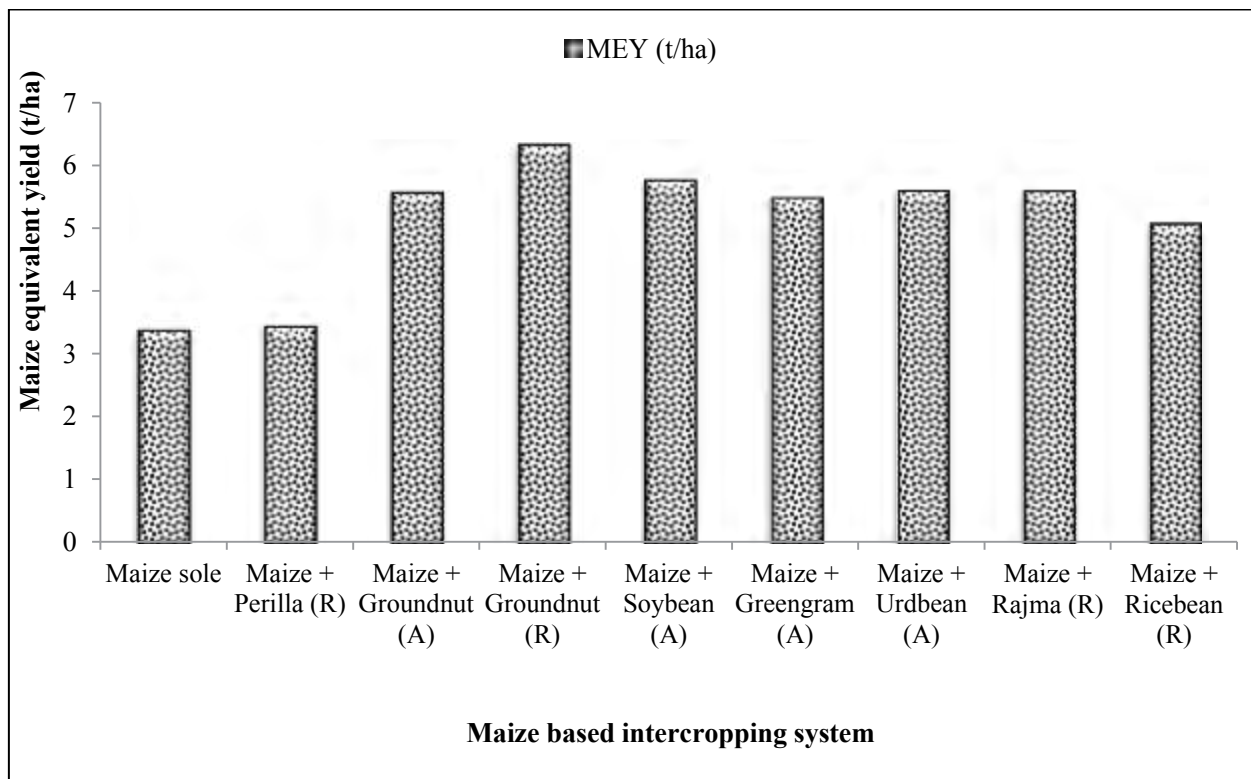


Figure. Maize equivalent yield and economics of maize intercropping systems
Note: MEY, A and R represents maize equivalent yield, additive and replacement series



Groundnut grown under additive and replacement series with maize in Churachandpur



Soybean and ricebean grown under replacement series with maize in Churachandpur

Other Promising Maize based cropping system:



Maize + Soybean intercropping



Maize + Carrot intercropping



Maize + Beans intercropping



Maize + Sunflower intercropping



Maize + Sweet potato intercropping



Maize + Cowpea intercropping

Liming of acidic soil

Liming means addition of any compound containing Calcium alone or both calcium and magnesium, that is capable of reducing the acidity of the soil. Lime correctly refers only to Calcium oxide (CaO), but the term as applied in agriculture is universally used to include various other materials also, like Calcium carbonate, Calcium hydroxide, Calcium - magnesium carbonate (marl) and Calcium silicate slags. Bacteria, that fix nitrogen in relation to the peanut plant, do better and form more nodules with an adequate calcium (Ca) level and with pH around 6.0 or higher. Generally soils of Manipur (both hills and valley) are acidic in nature and compulsorily require lime application. Apply 500 kg of lime/ha in furrows and properly mix thoroughly with the soil before sowing of the crops since it may take as long as 6 months for full reaction.



Nutrient management

Among all the cereals, maize in composite/local and hybrids in particular are responsive to nutrients applied either through organic or inorganic sources. The rate of nutrient application depends mainly on soil nutrient status/balance and cropping system. For obtaining desirable yields, the doses of applied nutrients should be matched with the soil supplying capacity and plant demand (site-specific nutrient management approach) by keeping in view of the preceding crop (cropping system). Response of maize to applied organic manures is notable and hence integrated nutrient management (INM) is very important strategy in maize based production systems. Therefore, for higher economic yield of maize, application of 10 t FYM ha⁻¹, 10-15 days prior to sowing supplemented with 100-120 kg N, 60 kg P, 60 kg K and 25 kg ZnSO₄ ha⁻¹ is recommended. Full doses of P, K and Zn should be applied as basal preferably drilling of fertilizers in bands along the seed using seed-cum-fertilizer drills. Nitrogen should be applied in various splits as detailed below for higher productivity and use efficiency. N application at grain filling results in better grain filling. Therefore, nitrogen should be applied in five splits as per below mentioned for higher N use efficiency.

S. No.	Crop	Nitrogen rate (%)
1.	Basal (at sowing)	20
2.	V4 (four leaf stage)	25
3.	V8 (eight leaf stage)	30
4.	VT (tasseling stage)	20
5.	GF (grain filling stage)	5

Precision nutrient management: There is huge variation in Indian soil w.r.t the nutrient various nutrients content and the respond to varied fertilizer application. The 4R principles of applying right nutrient source, at right rate, at right time and at right place is expected to increase nutrient use efficiency, productivity and farm profit from maize production and provides opportunity for better environmental soundness. In-season N application adjustments of maize can be done using leaf colour charts (LCC), SPAD and Green-Seeker sensors. The N requirement of crops at initial growth stage (V3 in maize) is comparatively less. It has been well established that maize begins to rapidly take up N after V6, with the maximum rate of uptake occurring near silking and the diagnostic techniques to monitor crop N status, such as the chlorophyll meter (SPAD-502), are good for N management. As a in-season crop N management strategies, skipping basal application and application of nitrogen as per critical SPAD values are beneficial for improving crop productivity.

Weed control: The chemical herbicide application for weeds control is quick and cheaper than mechanical methods and suitable under adverse weather conditions. Choice of herbicides, their dose and time of application are very important for obtaining higher weed control efficiency which is similar for both seasons. Several herbicides along with their dose and time of application recommended for controlling weeds in maize are given in Table 6. The tank mix application of atrazine + pendimethalin @ 0.50 + 0.75 kg a.i./ha before the emergence of both weeds and crops help[s in best weed control of the maize. However, alone application of atrazine @ 1.0-1.5 kg a.i./ha or pendimethalin @1.0 kg/ha pre-emergence also found effective for weed control in maize. The atrazine (0.75-1.0 kg a.i./ha) can also be applied as post emergence (15-20 days after sowing) without any toxic effect on maize plant, if the pre-emergence herbicide was not applied due to some reasons.

Conclusion

In nutshell, to increase area and production of maize crops we need crop specific and region specific approaches, which should be adopted in the overall framework of systems approach. There is need to integrate the production technology, dissemination, utilization and support systems for transfer of improved technology to get the maximum production of maize for the sustainable livelihood and food security in the region. There is urgent need of linkage between the public and private agencies to ensure the availability of latest technology, knowledge and empowerment of the stakeholders. Successful legume cultivation depends on the available resources and their proper utilization by the farming community to achieve maximum production and income from the landholding. In the uplands of the Eastern Himalayan Region (EHR) of India, rainfed maize is the second most important crop and occupies considerable area. Since, maize is an ingredient for feeds of animal, fish, poultry and cost of feed has risen very high. Maize is the most important emerging crop in the EHR. The average productivity of maize in Manipur is low (<2.0 ton ha⁻¹), as compared to other maize growing states and average productivity of India (2.43 ton ha⁻¹). Hence, there is an urgent need of addressing the farmer's requirement for enhancement of their productivity. Under the present scenario, attention is required to be given not only to technological backup, but also to make roadmap for technologies transformation to the farmer's field along with strengthening in value addition.

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CLIMATE RESILIENT MAIZE PRODUCTION TECHNOLOGIES FOR MEGHALAYA STATE

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Meghalaya (currently has 11 districts) is basically an agrarian state with about 80% of its population depends on agriculture for their livelihood. Being a mountainous state only 10% of the geographical area of Meghalaya is under cultivation. Maize, queen of cereals is the second most important food crop of Meghalaya after rice occupies about 18000 ha (8% of total area) with an average yield of 2150 kg/ha. In Meghalaya maize is mainly cultivated in upland traces during kharif season. The unique feature of this crop is interior diversity. Among the different corns, grain maize, sweet corn, baby corn and popcorn are mainly cultivated in Meghalaya. Maize is usually eaten after it is boiled in water, fried or burnt over fire. It sustains hunger for a longer period than rice. Farmers and manual workers of Meghalaya usually prepare food cooked with rice and maize. Firstly, grounded maize is boiled with water and then afterwards rice grains are added. This is a specially prepared dish which has a taste of its own and at the same time sustains hunger much longer. Maize has a better-withstanding capacity to climate change than other major cereal grain crop. Biologically, it has a C₄ mechanism of carbon fixation where loss of CO₂ during photosynthesis is very less and energy conversion efficiency is very high. Higher water use efficiency has resulted with higher CO₂ concentration with optimum inputs. But climate change is detrimental to maize production in Meghalaya where soils have degraded to an extent that they no longer provide adequate nutrients to buffer crops against multiple stresses. These effects will be most severe if drainage is not available to remove the excess water from the field. Improving genetic adaptation to multiples stresses alone will not address these problems there is also a need for complementary agronomic interventions. Maize faces problems during reproductive stage if stress affects in the form of more heat, drought, water logging etc. Waterlogging leads to increased anthesis-silking interval (ASI) ultimately poor yield. It is susceptible to soil pH change and nutrient imbalance as maize is an exhaustive crop. Among the cereals for changing climate, maize is the best option but still to prepare it as a future crop with appropriate agronomic interventions. Climate resilient sustainable maize production techniques are the set of site-specific adaptation strategies aimed to reduces the vulnerabilities and increasing the resilience of the production systems. Timely planting, proper drainage, optimum crop geometry, balance fertilization, crop establishment techniques, weed management and proper crop rotation is the key for obtaining higher maize yield in Meghalaya.

Adoption of conservation agriculture in maize based cropping systems

ICAR Research Complex for NEH Region, Umiam has developed improved cropping systems and management practices known as conservation agriculture (CA) as part of climate change adaptation options for Meghalaya region of North East India. It involves reductions in tillage activities, surface cover through retention of crop residues and intercropping, and diversified, ecologically sustainable and economically viable maize based cropping systems. This has contributed to productivity enhancement, and efficient utilization of available natural resources, as well as savings in labour and fuel costs. Furthermore, innovative agronomic and resource management practices, such as conservation agriculture (CA) and improved nutrient management, can contribute to climate change mitigation. CA also enhances soil carbon sequestration and reduces CO₂ emissions by reducing tillage intensities.

Climate resilient maize based cropping systems in Meghalaya

Productivity of rainfed monocropping system in Meghalaya is low and it is a high economic risk activity. Hence, multiple cropping (intercropping, relay cropping and mixed cropping) with multi-canopy structure and those that provide continuous vegetative cover throughout the year has suggested for better farm productivity. The sloping lands are 3-4 times less efficient than the plains in meeting the caloric and protein needs of their populations (Babu *et al.*, 2016). Hence, sustainable intensification is the need of hour to enhancing the farm productivity in hilly regions. Sustainable intensification is an agricultural production strategy that pursues to increase and optimize the benefits that can be derived from making better use of available natural resources. There is always need to consider agricultural options in context, taking full account of the factors and interactions of time and space so that field operations are conducted in a timely way, with land area optimally occupied by crops in system mode. Cropping system diversity can help build greater agro ecosystem resilience by suppressing biotic pressures and by mitigating effects of extreme and more variable weather. Following maize based climate resilient cropping systems are suggested for higher income, employments and better soil health in upland terraces of Meghalaya

- ❖ Maize-Frenchbean
- ❖ Maize-Toria
- ❖ Maize-Buckwheat
- ❖ Maize- Black gram/Green gram
- ❖ Maize-Frenchbean-Lentil
- ❖ Maize- Black gram/Green gram-Vegetable pea/Toria

Crop residue management (CRM) in maize based cropping systems

The proper management of crop residue provides a significant amount of nutrients for crop production, besides it improves the soil physical, chemical and biological functions and properties. Crop residue on the soil surface are known to reduce soil erosion either by affecting directly the physical force involved in erosion or indirectly by modifying the soil structure and soil biological regimes through organic matter (OM) addition. These stubbles and residues can be used as mulch which increases infiltration by reducing surface sealing and decreasing runoff velocity. The decomposition of the stubble and residues start after certain period of time and can have both positive as well as negative effect on crop production and environment. The crop residues serve as a habitat for insect-pest and disease pathogens which is considered as a major drawback of crop residue management (CRM). Hence, to increase the positive effect of CRM with minimum adverse effect on the environment, the crop residues and stubbles should be well managed. Leaving vegetative cover on the field through stubble and crop residues helps to ‘sew’ the soil and protect it from water erosion. These crop residues act as a feed for micro-organisms, thus enhance the biological activity which plays an important role in nutrient cycling. Composts from plant debris and animal manures added to the soil along with integrated biological pest and weed management, crop rotation and mechanical cultivation also helps to sustain and enhance soil productivity and fertility without the use of synthetic N fertilizer and pesticides. The handling of crop residues also has an impact on net carbon gains.

Strategies for nutrient conservation and fertilizer economy in maize based systems

In Meghalaya, farmers use very low level of fertilizers with less efficiency. A number of nutrient management practices are used to enhance fertilizer use efficiency (FUE) and reduce nutrient losses. The following practices are followed:

- ❖ Inclusion of at least one leguminous crop in crop rotation to fix the atmospheric nitrogen into the soil. Cover crops like groundnut are planted between crop seasons to tie up and preserve nutrients, in contrast to continuous planting of the maize and not planting any cover crops
- ❖ Grasses are grown on the bunds to mitigate soil erosion and conserve the nutrients
- ❖ Application of manure, organic waste based manure and incorporation of other byproducts into the soil should follow in nutrient management plan.
- ❖ Assessing nutrient need through annual or regular soil testing before applying nutrients
- ❖ Timing of nutrient application to tailor feeding to meet plant growth needs is important, for example, split application of nitrogen fertilizer in contrast to single application before planting.
- ❖ Application of conservation effective crop management practices like modified tillage and organic farming practices etc.

Efficient exploitation of indigenous maize germplasm for enhancing crop productivity

Climate change portends current agricultural output and, hence, there is a greater need to enhance agricultural yields and resilience of agro ecosystems as well as to improve the livelihoods of farmers. There is an urgent need to develop climate-adaptable crop varieties by proper exploitation of local land races with improved tolerance to multiple abiotic and biotic stresses.

Land development for enhancing maize productivity and reducing soil erosion

Sloping land comprises the major area in Meghalaya plateau and vulnerable to different kind of soil losses. Maize cultivation practices with appropriate agronomic interventions in sloppy land accelerated the soil erosion. Hence, inward sloping narrow bench terraces are suggested to arrest the soil and nutrient losses due to erosion and enhances the maize productivity. These are the trenches excavated along the contours to break the slope length for reducing the velocity of surface runoff. Planting of fodder grasses on terrace riser is advocated to reduce the soil erosion and nutrients losses besides providing the fodder to home cattle's. Perennial forage grasses like guinea grasses are growing on the terrace rises or bunds and it is most suitable for Meghalaya. It helps in preserving the soil by reducing soil loss from wind erosion, when soil structure is disturbed during land preparation. Contour-based cultivation, particularly when combined with grass planted in contour strips, is considered to be effective both in terms of control and costs in maize production systems. Conservation bench terraces have been found effective for maize cultivation on sloping lands. Bench terraces are generally more effective on slopes steeper than 12%. They are expensive, difficult to construct, require considerable technical supervision, and require departure from the existing agricultural practices of subsistence upland growers. They are prohibitively expensive in some developing countries and can occupy as much as 35% of the cropping area on 10-12% slopes. However, in systems where land use pressure is extremely high construction of terraces provides an effective, although labour intensive, form of soil conservation.

Maize based intercropping systems in Meghalaya

The most common goal of intercropping is to produce a greater yield on a given piece of land by making better utilization of available resources or ecological processes that would otherwise not been utilized by a single crop, leading to higher productivity per unit area. Cereal + legume intercropping reduce competition for N, since legume depends mainly on its own N₂ which is fixed by nodule into soil itself, while cereals use available mineral N. Nitrogen fixation potential is increased by growing legumes in intercropping rather growing any grasses or other crops. Legumes, with their adaptability to different cropping patterns and their ability to fix N, may offer opportunities to sustain and enhance soil health in hill ecosystem. Intercropping

systems have proved to be remunerative enterprises compared to sole cropping either of maize or legumes in mid hill sub-humid condition of Meghalaya. Legumes in maize-based cropping systems are considered to be better alternatives for securing nitrogen economy and increasing yield of maize besides bonus yield, greater productivity per unit time and space hence, intercropping is a less risky technology especially under changing climatic condition. Following maize based intercropping systems are suggested for improving land and water productivity in Meghalaya.

- ❖ Maize+Groundnut
- ❖ Maize+Rice bean
- ❖ Maize+ Soybean
- ❖ Maize+Cowpea

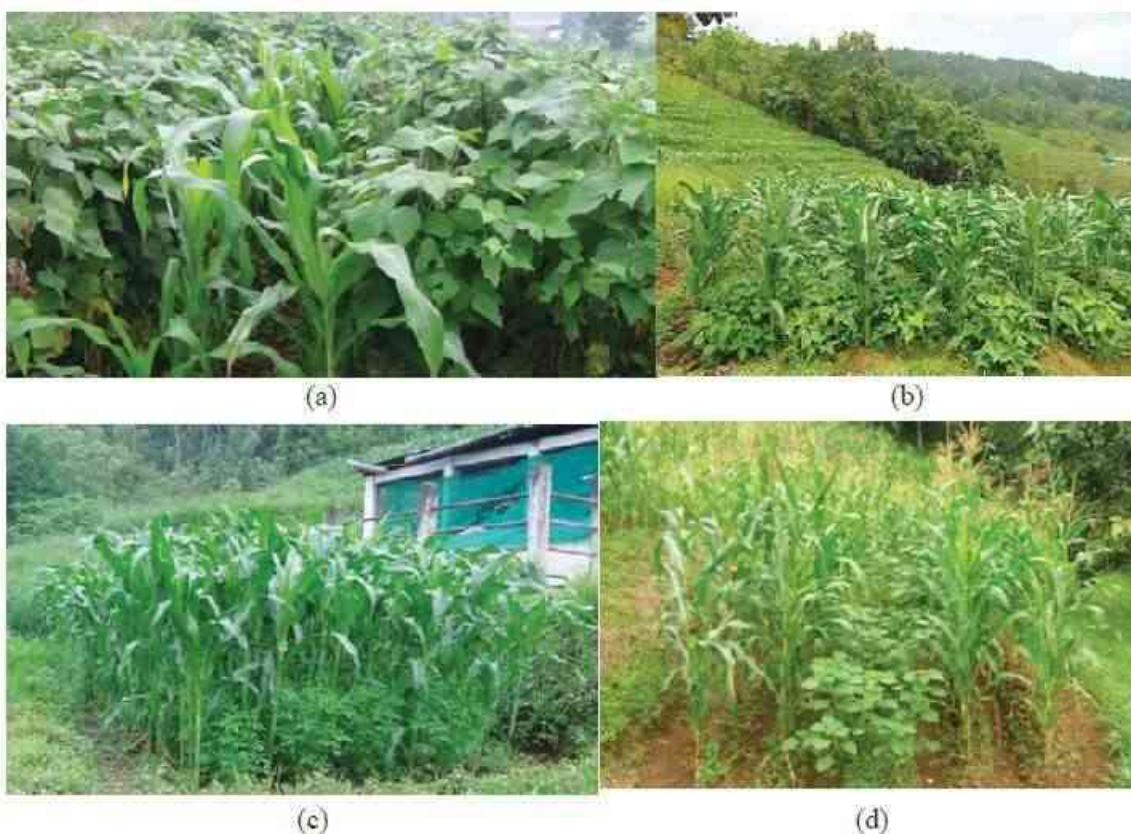


Fig. 1: (a) Maize + French bean intercropping (b) Maize + Rice bean (*Vigna umbellata*) intercropping (c) Maize + Soybean (*Glycine max*) intercropping (d) Maize + Ramie (*Boehmerianivea*) intercropping

Soils

Maize can survive in variety of soils ranging from loamy sand to clay loam. However, soils with good organic matter content having high water holding capacity with neutral pH are considered good for higher productivity. Maize is very sensitive to excess moisture stress; hence,

the fields having provision of proper drainage should be selected for cultivation of maize. Meghalaya soils are rich in organic carbon, which is a measure of nitrogen supplying potential of the soil, deficient in available phosphorous and medium to low in available potassium. The reaction of the soils varies from acidic (pH 5.0 to 6.0) to strongly acidic (pH 4.5 to 5.0). Therefore, liming is very important to correct the soil acidity for successful maize production in the state. Furrow application of lime (80 mesh size) @ 200-400 kg/ha is recommended for the soil having pH <5.5. Lime can be applied with basal dose of fertilizers (part of N + full dose of P & K) manually or through seed cum fertilizer drill at the time of sowing.

Time of sowing/planting

Being a photo-insensitive and day neutral plant, maize can be grown in all seasons *viz*; Kharif, post kharif monsoon, *Rabi* and spring. However, in Meghalaya maize is grown during pre-kharif/kharif season as a rainfed crop. Farmers of the Meghalaya are not cultivated the maize during winter season mainly due to lack of irrigation facilities. The optimum sowing time of kharif grain/popcorn in Meghalaya is May-June.

Seed rate and planting geometry

Optimum plant population is the key factor for achieving the higher productivity and resource-use efficiencies in any production system.

Importance of plant population / crop geometry

- ❖ Yield of any crop depends on final plant population
- ❖ Under rain fed conditions, comparatively lower plant population is require to utilize soil moisture judiciously in contrary when soil moisture and nutrients are not limited high plant population is necessary to utilize the other growth factors like solar radiation efficiently.
- ❖ Under low plant population individual plant yield will be more due to wide spacing.
- ❖ Under high plant population individual plant yield will be low due to narrow spacing leading to competition between plants.
- ❖ Yield per plant decreases gradually as plant population per unit area is increased, but yield per unit area increases up-to certain level of population. That level of plant population is called as optimum population. So to get maximum yield per unit area, optimum plant population is necessary.

The seed rate varies depending on purpose, seed size, plant type, season, soil type, sowing methods etc. The following crop geometry and seed rate should be adopted for profitable maize production in Meghalaya. The optimum seed rate and planting geometry is given in Table-1.

Table-1: Optimum seed rate and planting geometry of maize

Purpose of cultivation	Seed rate (kg/ha)	Planting geometry (Row x Plant cm)
Normal/QPM grain/green cob	18-20	60x20 for inorganic management 50x20 for organic management
Fodder	50-60	30x10
Pop corn	12-15	50x20
Baby corn	20-25	45x15

Sowing depth

Depth of sowing mainly related to coleoptile length and food reserve of the seed, however it also depends on soil type and management practices, in general sowing depth bold seeded crops are comparatively more than the small seeded crops. As a thumb rule maize seed should not be sown beyond the 5-7 cm, otherwise crop emergence and plant population affected adversely.

Varieties

The variety selection to a particular location is a key determinant for getting higher productivity and profitability of maize. Some of the important varieties suitable for Meghalaya are given here under

Maize type	Important Varieties
Normal grain maize	RCM1-1, RCM 1-76, RCM1-3 DA61-A, Vivek Maize Hybrid 51 &25, RCM 75
QPM	HQPM 1 & 5
Baby Corn	VL Makka 42, VL-45, MTH-14, RCM 1-1, RCM 1-3, HM-4 VL Baby corn-1 and MLY
Pop corn	Local, VL Amber popcorn 1
Fodder maize	Pratap Chari-1, RCM-1-3, DA61-A, African tall

Tillage and crop establishment

Tillage and crop establishment is the main driver of the crop yield. Crop establishment depends on interactions of seed, seedling depth, soil moisture, method of sowing, manuring, water management etc but, the method of planting plays a vital role for better establishment of

crop under a set of growing situation (Parihar *et al.*, 2011). Being a kharif crop maize experiences very intense rainfall and subjected to heavy lodging. Lodging of plants has a financial implication for the grower, because a number of cobs may be laying on the soil, making it uneconomical to be picked up by hand. Good progress has been made with cultivars showing less lodging, but differences among cultivars still occur. Therefore it is very important that different situations require different sowing methods for achieving higher yield as described below:

Raised bed (ridge) and furrow sowing

Generally the raised bed planting is considered as best planting method for maize in Meghalaya under excess moisture availability. Sowing should be done on the top or side of the ridge however, the southern side of the east-west ridges helps in good germination. The furrows facilitate the removal of excess water and crop can be saved from excess soil moisture stress. For realizing the full potential of the bed planting technology, permanent beds are advisable in mid slope areas wherein sowing can be done in a single pass without any preparatory tillage.

Zero-till sowing

The no-till system is a specialized type of conservation tillage consisting of a one-pass planting and fertilizer operation in which the soil and the surface residues are minimally disturbed. The surface residues of such a system are of critical importance for soil and water conservation. Maize can be successfully grown under no-till situation. In the sloppy terraces, the planting is done by manually by making small holes of 2-5 cm depth and drills the seed into it. No-tillage systems eliminate all pre-planting mechanical seedbed preparation except for the opening of a narrow (2-3 cm wide) strip or small hole in the ground for seed placement to ensure adequate seed/soil contact. The entire soil surface is covered by crop residue mulch. No-tillage maize production conserves soil and water and reduces capital investment in machinery for land preparations and intercultural operations, but most important to many producers, no-tillage can improve maize yields. No-till leaves the soil undisturbed from harvest to planting. This practice also leaves crop residues on the surface after planting, which promotes infiltration of rain falling months. However, use of appropriate planter having suitable furrow opener and seed metering system is the key of success of the no-till technology.

Yadav *et al* (2015) suggested the following conventional no till based land configurations for achieving higher maize productivity in high rainfall area of north east India.

- ❖ Conventional tillage with flatbed planting: –4 ploughing with the help of power tiller and plots should be prepared to ground level.

- ❖ Conventional tillage with ridge and furrow planting: The ridges and furrows are made from the surface, 15 cm deep furrow should be made and the removed soil should be placed on ridges, finally making 30 cm ridges from base.
- ❖ Conventional tillage with raised bed planting—the plots were ploughed conventionally but raised the planting area for about 15 cm above the ground.
- ❖ No-till with flatbed planting—residues of previously grown crop is left on the soil surface; a hand hoe should be used to open planting/sowing point.
- ❖ No-till with ridge and furrow planting—the ridges and furrows are made from the surface, 15 cm deep furrow should be made and the removed soil should be placed on ridges, finally making 30 cm ridges from base made in previous season and repaired in planting season to maintain no-till condition.
- ❖ No-till with raised bed planting (NT-RB)—the plots should be ploughed conventionally but raised the planting area for about 15 cm above the ground in previous season and repaired in planting season to maintain no-till condition.

However, Yadav *et al* (2018) also reported that among the land configurations, significantly higher soil moisture content (22.8–23.4% and 21.0–25.3%) was found in NT–RB system as compared those under CT–FB (19.0–19.4% and 17.0–21.2%) at 0–60 cm soil depth. Similarly the maximum number of cobs ha⁻¹ (63,518 cobs per plant), cob weight (272 g per cob), green cob (11.2 M ha⁻¹) and fodder yield (50.5 Mg ha⁻¹) were also recorded under NT–RB system. So, it is recommended to grow summer maize under NT–RB system for higher soil moisture conservation, improved plant growth and subsequently good fodder and green cob yield in the hills of NER.

Nutrient management

Maize is a most nutrient exhaustive crop and very responsive to external nutrients application. Ramkrushna *et al* (2018) suggested that the application of RDF (80:26.2:33.2 kg NPK/ha) +lime (250 kg/ha in furrows) + FYM (5 t/ha in furrows) [RDF + lime + FYM] substantially improves maize growth and productivity besides brought positive change in soil chemical properties. In general following fertilizer schedule should be adopted for achieving the maximum maize yield in Meghalaya

- ❖ Application of biofertilizer: 20-25 kg *Azospirillum* +*Phosphobacteria*/ha or Azophos 4 kg/ha should be applied before the sowing of the crop.
- ❖ Organic nutrient management: Integrated organic nutrient management strategies should be followed without excess reliance to any one organic sources of nutrient for economic maize production. Hence, 5-6 tonne FYM+ 1.5-2 tonne vermicompost +2 tonne poultry/pig manure should be applied 8-7 days before the sowing of crop for achieving optimum yield of maize crop.

- ❖ Inorganic nutrient management: 60-80 kg N+40 kg P₂O₅+ 40 kg K₂O/ha along with 25 kg ZnSO₄/ha should be applied for grain maize however, 25% higher dose of N is recommended for baby corn production.

Weed Control

In Meghalaya, weed control in maize is often more difficult than in plain areas. Application of forest litter and/or weed biomass @ 5-7.5 t/ha is recommended to suppress the weed flora in maize. In addition, during sunny days, application of Atrazine @ 0.25 kg/ha as pre emergence on 3-5 DAS using 500 L should be used to reduce the weed pressure under inorganic management. However, if maize is intercropped with pulses, spray of Pendimethalin @ 0.75 kg/ha as pre emergence is recommended.

Water management

Maize is susceptible to both excess and deficit moisture stress, adequate moisture supply is necessary to harvest good crop without negative yield penalty. Maize is grown as a rainfed crop in Meghalaya, hence didn't apply any irrigation. However, excess water is a problem due to high rainfall. Therefore, proper drainage of excess water should ensure for successful maize production in Meghalaya.

Harvesting

Maize crop for grain purpose should be harvested 25-30 days after tasseling, at this stage maize grain contains 22-25% moisture and husk turns pale brown colour. The harvesting of cob and stalk should be done separately or stalk cut method of whole plant harvesting followed by manual picking of cobs. The grain maize should be dried up to 12% moisture to reduce the post-harvest losses during storage. However, fodder maize should be harvested at any time before anthesis because after anthesis fodder quality deteriorated rapidly similarly harvesting of baby corn should also be started before anthesis when unfertilized cobs becomes one to three centimeter long (silk).

Conclusions

Climate change had relatively less detrimental effect on maize production as compare to rice and wheat hence, can be claimed as a futuristic crops. But appropriate breeding strategies and agronomic interventions should be evolved for sustainable maize production in hilly ecosystem. Innovative production technologies like location specific land configuration for sowing methods, cropping systems and integrated crop management practices must be adopted for improving the maize productivity mitigating the climate change impacts.

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MAIZE BASED CROPPING SYSTEM IN NEH REGION: STATUS, SCOPE AND STRATEGIES

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Multiple crops in an agro-ecosystem improve the ability to manage biotic and abiotic stresses as well as potentially improve the system productivity and environmental performance of the cropping system. Maize (*Zea mays* L) is a potential and predominant pre-rainy season crop on the hill ecosystems of North Eastern Region (NER) of India. Maize requires humid climate from the time of sowing to the end of its reproductive phase. Therefore, there is need to intensify existing maize–fallow systems with the inclusion of more number of crops per unit area. The NER has a potential to revolutionize the maize production of the country, given its naturally fertile soil having high organic carbon content (1-3.5%), a wide range of pH, diverse micro flora and fauna, and a good amount of drainage, the abundant water resources from the plenty of rainfall and a coordinial climatic conditions from an altitude of 20 m to more than 3000 m from sea level. A wide pedo-climatic variation provides an opportunity for year round cultivation of maize in this part of country. However, to boost up production under maize based cropping systems, an approach based capacity building of farmers through introduction of high yielding maize varieties/hybrids, conservation agriculture based production system, adequate and timely supply of quality seed and mechanization is the need of hour. For realizing actual potential, adequate emphasis must be given on quality seed production, mechanization, post-harvest processing and value addition and marketing which would contribute to enhancing farmers income and attract youths in farming.

Key words: Maize, Cropping system, intercropping, productivity, sequential cropping, multiple cropping

The North Eastern Hill (NEH) region of India, also called north-eastern Indian Himalayas comprises of eight states (Arunachal Pradesh, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, Tripura and Hilly tracts of Assam) and covers about 18 million hectare (M ha) area which is ~5.47% of total geographical area of India (329 M ha) (Das et al., 2018). The NEH, together with whole of the state of Assam, is popularly called the North Eastern Region (NER) of India which covers Agricultural activities up to 3500 m altitude and on slopes of up to 60%. The NER lies between 22°05' and 29°30' N latitudes and 87°55' and 97°24' E longitudes and is home to 45.5 million people in 2016. The majority of livelihoods in the Himalayan region are based on agriculture and land is the most vital component of all socioeconomic activities. The

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Region shows a great differentiation in pedo-climatic, geological, vegetation, and other features due to complex variegation of agroecosystems which leads to diverse agroecological zones. Agriculture is the important source of livelihood of the region, and after rice (*Oryza sativa* L), maize (*Zea mays* L.) is the second most important crops of the entire NER (Ansari et al., 2015). Unsustainable agricultural practices, such as monocropping, conventional tillage, indiscriminate use of fertilizers and pesticides, etc., apart from land degradation and cropland scarcity have serious implications for livelihood security in NER (Yadav et al., 2018). Under such scenario, there is a need to diversify cropping pattern to make the entire agricultural system sustainable and environmentally secure. Maize is a potential and predominant pre-rainy season crop on the hill ecosystems of NER, India (Ansari et al., 2015). Maize requires humid climate from the time of sowing to the end of its reproductive phase. Extremely high temperature and low humidity during flowering period desiccates the pollen and interfere with proper pollination which results in poor grain formation. Optimum rainfall requirement for proper growth and development lies within the range of 50 cm to 75 cm. Moisture stress during flowering stage should be avoided as it causes maximum yield loss. Maize usually grows well under temperatures varying from 21°C to 27°C, although it can tolerate temperatures as high as 35°C (Ansari et al., 2015). Frost is injurious to maize and this crop is grown only in those areas where there are about four and a half frost free months in a year. Lowest mean temperature for sowing of maize is 10°C but optimum temperature for proper germination is 18°C -20°C. Minimum soil temperature at the time of sowing should not be less than 12°C. Due to growing market demand of fresh cobs and increasing deficit of fodder in the region, and more favorable climatic condition, farmers are growing maize in all the season in NER (Yadav et al., 2018). However, the productivity of maize is low (<1.5 t ha⁻¹) and uncertain due to lack of assured irrigation and low residual soil moisture. The NER of India is a highly fragile ecosystem under sub-humid climate. Although the crop is also very popular in the low- and mid-hill areas of the NEH regions. It is also grown under jhum land and terraced area (Ansari et al., 2015). Therefore, it is dire need of the region to intensify the maize based cropping system with inclusion of suitable legume, oilseeds, and vegetables to enhance the overall system productivity.

Multiple crops in an agro-ecosystem improve the ability to manage biotic and abiotic stresses as well as potentially improve the system productivity and environmental performance of the cropping system. Therefore, there is need to intensify existing maize–fallow systems with the inclusion of more number of crops per unit area. However, the intensified production systems require increased use of energy and other production inputs. Hence, selection of appropriate-vital crops having higher resource use efficiency in maize–based cropping system is required to harness the maximum returns and enhance the flexibility of cropping under limited moisture supply without considerable modification in farming operations. This is of paramount importance for self–reliance in food and nutrition. In view of the limited scope for horizontal expansion to augment food production, the alternative is to proceed with vertical growth by

increasing the productivity per unit of available land. Therefore, maize based cropping systems will help the farmers to grow two or more crops in a year instead of one crop grown traditionally. Intercropping is advanced management practices of soil fertility status, consisting of cultivating two or more crops in the same space at the same time, which have been practiced in past decades and achieved the goals of agriculture. The most common advantage of intercropping is the production of greater yield on a given piece of land by making more efficient use of the available resources using a mixture of crops of different rooting ability, canopy structure, height, and nutrient requirements based on the complementary utilization of growth resources by the component crops. Moreover, intercropping improves soil fertility through atmosphere nitrogen fixation from atmosphere with the use of legumes, increases soil conservation through greater ground cover than sole cropping. Also, intercropping systems are beneficial to the smallholder farmers in the low-input and/or high-risk environment of the sub-tropic, where intercropping of maize and legumes is widespread among smallholder farmers due to the ability of the legume to contribute to addressing the problem of declining levels of soil fertility (Das et al., 2018). The principal reasons for smallholder farmers to practice intercropping are flexibility, profit maximization, risk minimization, soil conservation, improvement of soil fertility, weed, pests and diseases minimizing and balanced nutrition.

A state -of-art of different maize-based cropping system for the NER to boost up the productivity and to enhance the ecosystem services in the region is presented herein.

Maize based cropping systems of Sikkim

In Sikkim among the cultivated crops, maize covers maximum area (40,000 ha) and is sown in the pre-kharif season starting from February to mid-March. Most of the areas (about 60-70%) after maize harvest are vacant and only in some pockets farmers grow black gram and rice bean. Even after harvesting of maize, heavy rainfall hampers the sowing of pulses due to water logging and higher moisture in soil at the time of sowing and moisture scarcity in latter phase of crop growth. Hence, it may not be possible to plough the field for sowing of next crop during the season (Singh et al 2017). Hence, ICAR-NOFRI (formerly ICAR Sikkim Centre) has developed no-till technology for the cultivation of second and third crops in diversified cropping systems involving maize as main crop.

Maize- legume cropping systems

Inclusion of short duration pulses like black gram, rajmash and pea may be the options for enhancing the cropping intensity up to 200% in the state. ICAR Sikkim Centre identified maize – black gram, maize + bean– rajmash and maize + bean – pea in those area where irrigation facilities are not available (Singh et al., 2018).

No-till based maize -legume systems

Generally, farmers grow rajmash during Kharif season after harvesting maize without considering the drainage of the field. Similarly, more tillage operations affected by the farmers for sowing of rajmash which requires bigger window. However, no-till and/or reduced tillage technology makes cultivation more farmer friendly and saves time and input as well as produces healthy crops. Hence, to reduce the labour cost and time for preparation of land form sowing after harvest of maize, ICAR Sikkim developed no-till technology for sowing of black gram and rajmash immediately after harvesting of maize. After harvesting of maize field should be cleaned by removing all the debris remaining on surface. FYM or mixed compost @ 5 t/ha should be applied as basal application prior to sowing followed by goat manure/poultry manure @ 1-2 t/ha as basal dose to overcome micronutrient deficiencies. Before sowing, seed should be treated with Rhizobium and PSB @ 200 g/kg seed. Around 20-25 kg seed is required for a hectare of land for black gram and 75-80 kg/ha seed is required for sowing of rajmash (Babu et al., 2016). Sowing is done by opening a narrow slit (5-8 cm depth) for placement of seed at 30-40 cm row to row and 10-15 cm plant to plant distance. The results of the study recorded rajmash grain yield (1.37 t/ha) 17.8 per cent higher over conventional tillage (CT). Similarly, the black gram yield was also higher under NT planting (0.98 t/ha) over CT (Singh et al., 2018).

Maize-based cropping systems for irrigated condition

Sikkim has only 11% irrigated area and farmers generally leave their land fallow after harvest of pre-kharif maize due unavailability of critical planting material and lack of awareness. However, some farmers follow the cereal - cereal (pre-kharif maize and kharif rice) cropping system, which is highly nutrient exhaustive and therefore, its continuous use has depleted inherent soil fertility, causing deficiency of several nutrients and poor crop productivity, which in turns squat the economic returns and farmers losing their interest in agriculture (Babu et al., 2016; Singh et al., 2018). Since, sustainability of the production system depends on the optimum use of resources, it is necessary to develop and adopt soil management technologies that increase soil organic matter contents and biological activities, reduce acidity and improve soil physical conditions to keep lands productive on the sustainable basis. Induction of high value vegetables, legumes and oil seed crops along with precise conservation agricultural practices in the existing maize-based cropping system can improve the soil fertility and crops productivity on sustainable basis. Conservation agriculture with diversified maize-based cropping systems through inclusion of legume crops in sequence will help to overcome the major challenges viz., declining factor productivity and deterioration of the resource base and play vital role in sustainable agricultural production. Therefore, crop diversification is important for achieving stable food supplies in the state and for earning extra income. Hence, the impetus toward maize based system

diversification in irrigated condition is crucial. Some of the prominent existing and improved maize-based cropping systems are given hereunder.

Existing Cropping Systems

- Maize-fallow
- Maize-rice
- Maize-buckwheat

Diversified/Intensified Cropping Systems

- Maize+beans-vegetable pea
- Maize-Pahenlo dal-cole crops
- Maize-Pahenlo dal-coriander
- Maize (green cobs)-Pahenlo dal-fenugreek (leafy vegetable)
- Maize-French bean-vegetables (cauliflower/broccoli/cabbage/Spinach)
- Maize (green cobs)-Pahenlo dal/Kalo dal-vegetable pea
- Maize (green cobs)-rice-vegetable pea/coriander/fenugreek (leaves)
- Maize-Pahenlo dal-leafy mustard

ICAR-NOFRI has designed the following diversified/intensified cropping systems with zero irrigation having 200-300% cropping intensity for profit maximization per unit of land and input applied for rainfed ecosystems of Sikkim (Singh et al., 2018).

- Maize (green cobs)-Pahenlo dal-buckwheat/toria
- Maize+beans-vegetable pea
- Maize+beans-rajmash
- Maize+beans-buckwheat
- Maize-black gram/green gram/French bean

Maize based system for Meghalaya

It is better to grow a legume as intercrop in maize for enhancing soil fertility and productivity of system. In high altitude, Maize + soybean (one row of soybean in between two rows of maize) is very good intercropping practice for the region. In maize + soybean intercropping, soybean detopping is may be practiced in high rain fall area, which adds 8-10 kg N/ha and also improve the productivity of system (Das et al. 2014). In mid and low altitude area Maize + arhar (1:1 ratio) or Maize + groundnut/soybean and maize + rice bean is highly promising intercropping system. Paired row planting (2:2 row ratio) should be done for intercropping by adjusting spacing of the maize crop.

Cropping sequence

High altitude

- Maize + soybean

Mid & low altitude

- Maize-French bean,
- Maize-vegetables
- Maize-pea (for vegetable purpose, 70 days duration)
- Maize (fodder)-Rice (early variety sown at the end of June)
- Maize + Soybean (2:2)- mustard
- Maize + Groundnut (2:2) – toria
- Maize + Groundnut (2:2) – carrot
- Maize-mustard,
- Maize + French bean-mustard
- Maize + soybean 2:2 (kharif) - mustard (rabi)
- Maize + soybean 2:2 (kharif) Frenchbean (pre-rabi)
- Maize + groundnut 1:2 (kharif) –mustard (rabi)
- Maize - Carrot – Frenchbean (Upland)
- Maize - Frenchbean-Tomato (Upland)
- Maize - Frenchbean-Toria (Upland)
- Maize-tomato

Maize based cropping system for Manipur

In Manipur, area under maize cultivation is 19,440 ha with a productivity of 2.29 t/ha (Ansari et al., 2015). Cropping systems are the outcome of the technological innovations, household needs, reflection of government policies, availability of production inputs, market forces and socio-economic compulsion. An ideal cropping system should use natural resources efficiently, provide stable and high returns and do not damage the ecological balance (Ansari et al., 2015). Cropping system is broadly grouped into sequential cropping and intercropping.

Maize based sequential cropping

Multiple cropping in which crops are grown in sequence on the same field, with the succeeding crop planted after the preceding crop is harvested.

- Maize-Pea
- Maize- Rapeseed and mustard
- Maize- Lentil
- Maize – Lathyrus
- Maize-Vegetables
- Maize-Beans

Maize based intercropping

It is a multiple cropping practice involving growing two or more crops in proximity. The most common goal of intercropping is to produce a greater yield on a given piece of land by making use of resources that would otherwise not be utilized by a single crop.

- Maize + Groundnut
- Maize + Ricebean
- Maize + Soybean
- Maize + Mungbean/Urdbean

Maize based cropping systems for Tripura

Reduced tillage cultivation of hybrid maize in rice fallow land (Rice-maize cropping system)

Maize is one of the most important crops for medium upland under limited irrigation water supply. Where water is scarce resource during the summer season and growing of other crops, which require more water is not possible. Maize can be grown successfully with very small amount of irrigation water. Growing of hybrid maize with appropriate agro-techniques can enhance the productivity and income of the farmers. Two hybrid maize DHM-849 and HQPM-1 were tested under reduced tillage on farmer's field. Reduced the number tillage in such level which do not affect the crop yield, but reduces the cost of production significantly. In Tripura, mostly ploughing is done by the power tiller, which leads to high cost of cultivation. Under conditions of high and low soil moisture, reduced tillage performs better than zero tillage. In low moisture condition, it conserves the moisture through breaking soil crust and in high moisture conditions it reduced moisture by opening soil and makes it favourable for sowing. Cultivation of maize for green cob produced 6.2 and 6.5 t cobs/ha (Table 1) under conventional and reduced tillage system respectively. However, reduced tillage produced more yield as compared to conventional tillage. Farmer of Barkhathal, Mohanpur, West Tripura could earn a net income about Rs. 93425/ha and Rs. 76532/ha under reduced and conventional tillage system, respectively. Although reduced tillage gave more income and showed highest Benefit: Cost ratio as compared to conventional tillage. The cultivation of maize gave the extra income to the farmers over those left there field fallow after harvest of rice besides that cultivation of maize diversified the rice based cropping system and increase the cropping intensity.



Table 1 Effect of reduced and conventional tillage on productivity and economics of maize produced for green cob in farmers field

Particulars	Reduced tillage	Conventional tillage
Green cob yield (t ha ⁻¹)	6.5	6.2
Green fodder yield (t ha ⁻¹)	30.0	28.0

Cost of cultivation (Rs. ha ⁻¹)	22575	27468
Return from green cob (Rs. ha ⁻¹)	116000	104000
Return from green fodder (Rs. ha ⁻¹)	30000	28000
Total return (Rs. ha ⁻¹)*	116000	104000
Net return (Rs. ha ⁻¹)	93425	76532
B: C ratio	5.14	3.79

* Excluding the return from green fodder because farmers are not able to sell the fodder

Diversification of rice – fallow cropping system through maize

An experiment was conducted on ICAR NEH Tripura Centre research farm on diversification of rice – fallow cropping system. Different crops were introduced as substitution of the rice crop and in place of fallow with lifesaving irrigation. The results revealed that diversification of rice – fallow cropping system with different crops, increased the system productivity. Green cob maize –maize for grain – field pea cropping system recorded highest system productivity followed by ground nut – potato, which was higher than rice – fallow and rice – toria cropping system (Table 2) under upland conditions. In another experiment, the rice-vegetable system produces the highest yield and give highest net return with a similar cost of cultivation in comparison to other systems (Figure 1) under lowland condition.

Table 2 Effect of different cropping system on system productivity under upland condition

Cropping system	Yield of 1 st crop (t/ha)	Yield of 2 nd crop (t/ha)	Yield of 3 rd crop (t/ha)	System productivity (REY t/ha)
Rice – fallow	2.5	-	-	2.5
Rice – toria	3.2	1.25	-	8.2
Green cob maize – grain maize – field pea	10.3	5.44	0.90	49.2
Ground nut – potato	2.40	12.0	-	19.2
Green gram – groundnut	0.85	2.22	-	12.3

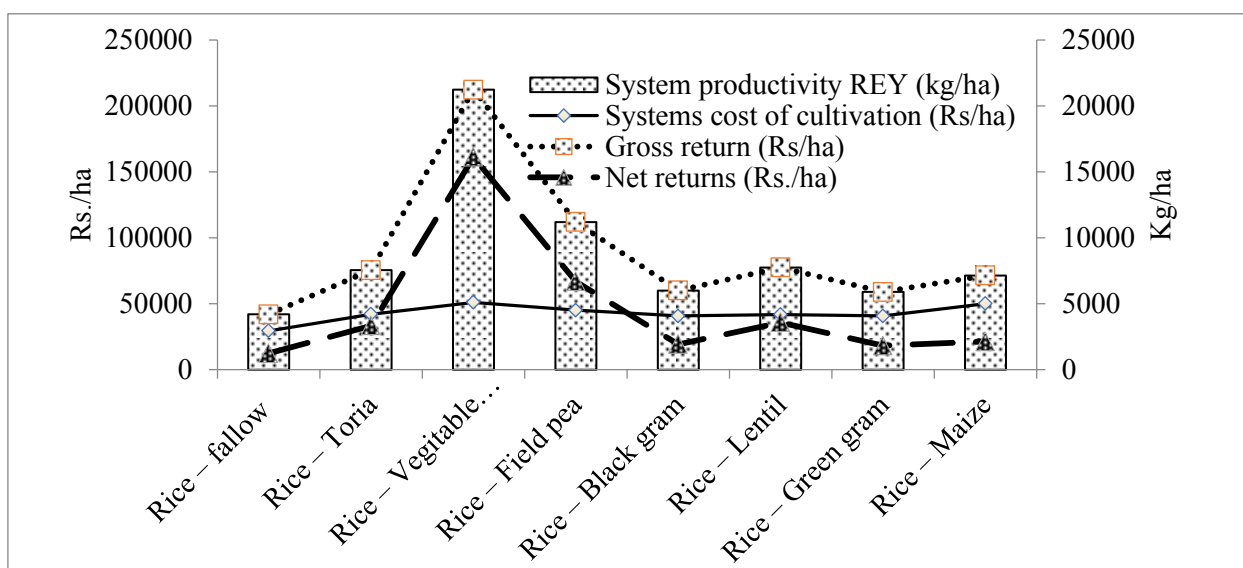


Figure 1: Effect of crop diversification and intensification on productivity and profitability of rice – fallow system under valley land/low land condition

Maize cropping systems for Mizoram

Most popular maize based cropping systems grown in Mizoram are maize+cowpea, maize+urdbean/greengram, maize-mustard and maize-French bean.

Maize based cropping systems for Nagaland

Maize is also important crop in Nagaland. Here, it mostly grown with rice under Jhum system. But in valley areas, crops like mustard, field pea, vegetable pea, French bean are grown after harvest of maize. During rainy season, crops such as groundnut, green gram etc. can be grown as intercrop to enhance the productivity and profitability of the farmers.

Maize based cropping systems for Arunachal Pradesh

The common maize based cropping systems grown in Arunachal are maize + cowpea, maize + urdbean/greengram, maize-mustard, maize-vegetable pea and maize-French bean.

Scope of Maize in NER

- The NER of India, of course, has a potential to revolutionize the maize production of the country, given its naturally fertile soil having high organic carbon content (1-3.5%), a wide range of pH, diverse micro flora and fauna, and a good amount of drainage, the abundant water resources from the plenty of rainfall and a cordinal climatic conditions from an altitude of 50 m to more than 3000 m from sea level. In addition to this, a wide pedo-climatic variation provides an opportunity for year round cultivation of maize in

this part of country. Furthermore, region is blessed with range of indigenous legumes with a great potential of nitrogen fixation provides another window for expansion of maize based cropping system in the region.

- With this vast land area and a range of climates and seasons, the NER is naturally suited to maize cultivation round the year.
- A large and growing middle income population provides a big human resource as well as consumption base for maize-derived food-direct or indirect.
- A strong R&D set up provided by ICAR-NEH with a large portfolio for development hybrids/improved varieties, germplasm and technologies.
- Stagnating yield of rice in the region, where maize can be suitably included for diversification.
- Rising incomes will lead to higher spending on non-crop food, ensuring a strong domestic demand for livestock-based food.
- Nearly 40-45 per cent of maize area still under non-hybrid, provides ample scope to increase productivity and production and thus profitability to the maize growers.
- Poultry industry is heavily dependent on maize as it forms 50-60 per cent of the input required for broiler feed and 25-35 per cent of the input required for layer feed. Maize is the preferred source of energy in feed when compared with other substitutes due to availability, higher energy and price economics. Poultry feed's share has remained around 45-50 per cent of the total demand for maize in the country over the past 4-5 years.
- Maize is the basic raw material required for manufacturing starch and constitutes 60-70 per cent of the total operating costs. Maize has 60-65 per cent starch content, hence cannot be easily substituted by other commodities.

Strategies

- Introduction of suitable high-yielding maize hybrid/varieties for diverse upland situations, flood affected areas, moisture stress conditions, and hill areas
- Introduction of short duration maize hybrid for rice fallow to utilize the residual moisture
- Development of region and location specific maize varieties and hybrids
- Development of infrastructure for storage and handling of maize seeds to deal with humidity, pest and diseases, sorting, grading etc.
- Promotion of no-till/conservation tillage based production technology
- Availability of quality seed and inputs
- Development of improved crop management practices for shifting cultivation with the inclusion of maize based cropping systems
- Improvement and standardization of production techniques for maize based cropping systems suitable to diverse physiographic region of NER

- Use of improved post harvest management including pest and disease management and processing techniques for maize based cropping systems
- Maize responds very well to liming. Hence low cost soil acidity ameliorating measures like furrow lining, seed pelleting, use of hydrogel etc., should be standardized.
- Proper market linkages from producers to industries
- Mechanization, especially for sowing, weeding and threshing and value addition
- Capacity building of farmers about production and marketing of maize
- Promotion of reduced/no tillage based maize production technology to reduce cost of cultivation and conserve natural resources.

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CLIMATE RESILIENT MAIZE PRODUCTION TECHNOLOGIES IN NAGALAND

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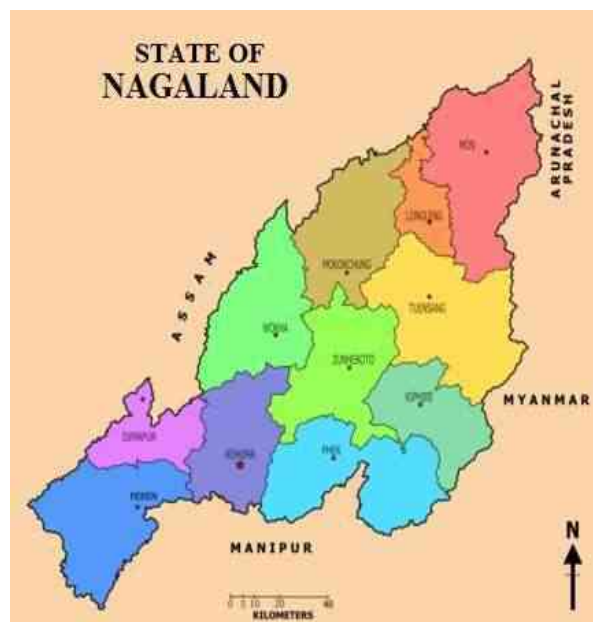
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Nagaland is a hilly and mountainous State. Agriculture has traditionally been and continues to be the mainstay and economic activity of Naga life- the numerous festivals revolve around the agriculture calendar and have their roots in cultivation practices. Seventy one percent of the populations are engaged in agriculture. Rice is the staple food which occupies about seventy percent of the total cultivated area and constitutes about seventy five percent of the total grain production in the State. The average consumption of rice in Nagaland is estimated at 540 grams per day per head. Urban consumption averages 485 grams per day per head and rural constitutes an average of 596 grams per day per head. Other principal crops include maize, pulses, oilseeds, sugarcane, potatoes and fibres.

The major crops grown in the State are rice, maize, millet, pulses, oilseeds, sugarcane, potatoes and fibres. Maize is the major crop after rice and also the staple diet of the people.

Some Basic Information:

- ❖ Area : 16,579 Sq. Km
- ❖ Population : 1980602 (2011 census)
- ❖ Density of population : 119/ Sq. Km
- ❖ Net sown area : 2,99,480 ha.
- ❖ Gross crop area: 3,84,180 ha.
- ❖ Net area irrigated : 83,500 ha.
- ❖ Cropping intensity 129 %
- ❖ Literacy rate: 80.1%
(Female :76.7% with male literacy
at 83.3%)



**Projected population and requirement of food for Nagaland up to 2025 item Population
(as per 2011 census and Projected population)**

Items	Projected population and requirement of food			
	2011	2015	2020	2025
Projected population	1980602	2186214	2473500	2798539
Cereals (MT)	361460	398984	451414	510733
Pulses (MT)	28917	31919	36113	40859
Oil (K.lts)	21688	23939	27085	30644

N.B. Calculating on the basis of cereal 500 gms, pulse 40gms, and oil 30ml per day per head, Growth assumed @ 2.5% per annum

Physical feature

Climate and rainfall – The climate of Nagaland varies from sub-tropical to temperate with heavy monsoon activity. The annual rainfall varies from 1500-2500 mm prevailing seven months from April to October. The temperature varies from 4⁰ C in winter to 35⁰ C during summer.

Agro climatic zone – The State falls under Mid Tropical Hill Zone category. The three distinct geographical regions are:

- (i) High Hill areas with lateritic soil and non laterised red soils.
- (ii) Lower hill ranges of brown forest soils and podzolic soil and
- (iii) Foothills and valleys with recent alluvial, old alluvial and mountain soils.

Soil– The systematic survey and classification of soils in Nagaland has revealed that the soil in the State is suitable for extensive crop cultivation.

Demography: The State is predominantly of tribal population comprising 16 different tribes besides other communities hailing from the rest of the country. The major tribes being, Angami, Ao, Chakhesang, Chang, Khamniungan, Konyak, Lotha, Phom, Pochury, Rengma, Sangtam, Sumi, Yimchungr, and Zeliang. The Angami, Ao, Konyak and Sumi are the larger Naga tribes. Collectively the Naga tribes speak 60 different dialects belonging to the Sino-Tibetan family of languages. Each tribe has its own dialect and within the same tribe multiple dialects. Nagamese,

a variant patois drawn from Assamese and Hindi is the language of communication between the multiple tribes. However, English is the official language of the State

Cultivation practices of Nagaland:

Two methods of cultivation practiced by the Naga tribes are *Jhum* or shifting cultivation and terrace cultivation. The current area (2010-2011) under *Jhum* cultivation is about 93,000 hectares while terraced cultivation is about 83,500 hectares. *Jhuming* has its obvious disadvantages as large tracts of land are required for cultivation. The shifting cultivation is a traditional agricultural practice with high incidences of soil erosion and loss of fertility, due to the reduction of periodicity in the *Jhum* cycle. In the past, *Jhum* was not so detrimental because the long periodicity of the cycle allowed the soil to regain its lost fertility. But now with the increased population pressure the *Jhum* cycle has been reduced to 2-3 years, as a result soil is becoming unproductive. Therefore, proper planning and management of *Jhum* cultivation is urgently required, while a gradual shift towards settled cultivation is the need of the hour to feed the ever growing population. It is not possible to eradicate *Jhum* cultivation because of its links to socio-customary agrarian practices by the people in the State. However, a more eco-friendly method is that of preparing terraced fields for cultivation.

Climate Change in Nagaland:

In recent years due to massive deforestation coupled with climate change, the climate of Nagaland has changed tremendously. The annual average rainfall has abruptly changed giving rise to the surface temperature in the State.

Temperature change in Nagaland: In this study, the kriging method was used to understand the present and future surface temperature changes in the State of Nagaland. Kriging is a group of geo-statistical techniques to interpolate the value of a random field (e.g. the surface temperature of a location) at an unobserved location from observations of its value at nearby locations. This method was used to understand the changes in surface temperature in Nagaland. Surface temperature data was collected from the thermal band of MODIS (TERRA) satellite developed by NASA. Although kriging was developed originally for applications in geo-statistics, it is a general method of statistical interpolation that can be applied within any discipline to sampled data from random fields that satisfy the appropriate mathematical assumptions. The result shows a massive increase of temperature from 2011 to 2018 and estimates up to 2026 in the state. These changes in temperature will be mainly due to the massive decrease of forest cover in the state from 1987 to date. The following remarks show the present surface temperature and future surface temperature in the State of Nagaland.

1. It is evident that the minimum temperature in the state of Nagaland is 5° Celsius and highest temperature is 33° Celsius. This is the present temperature pattern of the state.
2. The predicted average temperature in the year 2018. The minimum temperature of the state will be 17° Celsius and the maximum will be 36° Celsius. This indicates that the effect of climate change in the State of Nagaland will be quite significant in the year 2018. This change will affect the forest cover of the state and also the livelihood pattern of the people of the state by 2018.
3. The minimum temperature of the state will rise up to 20° Celsius and the maximum temperature of the state will be 35° Celsius.

The above shows that there will be a substantial increase of minimum temperature in the State from 5° Celsius in the year 2011 to 17° Celsius in the year 2018, and again up to 20° Celsius in the year 2026. But the increasing trend of maximum temperature in the State is not so significant. It indicates that the minimum temperature will increase and this will affect the plants and animals of the State.

Production system of different cereals in Nagaland

1. Paddy - Two types of production systems as given below are followed by the farmers of Nagaland for paddy production.
 - ✓ Jhum (shifting) cultivation of traditional varieties in rain-fed condition in hills and slopes.
 - ✓ Wet Rice culture (WRC) of traditional varieties and HYV in both rain-fed and irrigated conditions in plains and terraces
2. Maize - It is extensively cultivated as a mixed crop in *Jhum* cultivation under rain-fed condition and also as mono crop in settled cultivation in some areas.
3. Millet - Millets are mainly cultivated as a mixed crop in *Jhum* cultivation under rain-fed condition.
4. Pulse production system- Kholar (Rajmah) is the predominant pulse in the State. Besides this, other pulses such as lentil, green gram, pea are also cultivated. Pulses are generally cultivated as a mixed/ intercrop with maize in *Jhum*.
5. Oilseed production system- Rape and mustard is the predominant oilseed crop grown in *Jhum* as well as in settled cultivation under rain-fed condition. Besides this, soybean, linseed, niger, and sesamum are also grown in the State.

Table-1. Basic area & production of Major Field crops in Nagaland

Sl. no	crop	Area	Productivity (MT /ha)	Production (MT)
1	Paddy, Maize etc	224779	1.40	314691
2	Pulses	23662	1.00	23662
3	Oilseed	48222	0.83	40024

Maize Production in Nagaland: Scope and opportunities

Maize is a warm weather plant. It grows from sea level to 3000 metres altitude. It can be grown in diverse condition. It is grown in many part of the country throughout the year. Maize is very sensitive to stagnant water, particularly during its early growth stages.

The general climatic requirement for maize cultivation is as follows:

- 1. Temperature:** Maize is grown in temperatures between 18°C and 27°C during the day and around 14°C during the night. But the most important factor is the 140 frost-free days. The crop is very susceptible to frost; therefore, its cultivation in temperate latitudes is limited.
- 2. Rainfall:** Maize is grown mostly in regions having annual rainfall between 60 cm to 110 cm. But it is also grown in areas having rainfall of about 40 cm.
- 3. Soil:** Maize grows in a wide range of soils, ranging from temperate podzols to the leached red soils of the tropics (pH 5.5-7.5). But, the best suitable soil for maize is deep, rich soils of the sub-tropics, where there is abundant nitrogen.
- 4. Topography:** The plain regions are most suitable for maize cultivation. Although, maize is also cultivated on undulating lands of hills. Maize is also grown as a major crop of shifting cultivation.
- 5. Economic Condition:** Unlike other crops maize can be cultivated with small capital. Uses of machines have reduced the labour requirements. Most of the maize grown is utilised within the country, although its limited international trade is also there.

District wise maize production technology:

- 1. Dimapur:** Dimapur district is predominantly located in the plain region of the State except for one block. Three blocks share identical characteristics in topography, soil and rainfall. These blocks are Dhansiripar, Niuland and Kuhuboto. Medziphema block is at a higher altitude. The district can be divided on the following agro ecological situation.

- ✓ AES-1 (Plains and foot-hill) 0 - 600 m MSL: Rice is the predominant crop in this AES, beside rice, **maize**, pulses, vegetables and oilseeds are grown.
- ✓ AES-2 (Mid hill) 600-1200 m MSL. : Rice, **maize**, pulses, oilseed, vegetables and fruits are grown

Maize - It is extensively cultivated as a mixed crop in Jhum cultivation in 1824 ha of land with a production of 32832 tonnes and productivity 1.8t/ha under rain-fed conditions and also as mono crop in settled cultivations. millet -Millets are mainly cultivated as a mixed crop in Jhum cultivation under rain-fed conditions.

Table-2. Area & production of Major Field crops in Dimapur

Sl.no	Name of crops	Area covered (ha)	Production (in mt)	Productivity (qtls./ha)
1	Paddy (Jhum & TRC)	20880	41760	20
2	Maize	1824	32832	18
3	Mustard	4800	4800	10
4	Other pulses	1110	39895	7

2. **Kohima** Agro-ecological Situation of the District: Kohima district can be divided into two broad categories depending upon agro-ecological conditions.

- ✓ AES-2 (Mid Hill) Altitude from 600 - 1500 m MSL.
- ✓ **AES-3** (High Hill) Altitude from 1500 m - 3048 m MSL.

Paddy, **maize**, ginger, chillies, tomato, colocasia, banana, vegetables, piggery and poultry are some common agricultural activities in Agro ecosystem-II.

In Agro ecosystem-III the major agricultural activities are paddy, **maize**, potato, temperate fruits, floriculture and forestry. Maize is extensively cultivated as a mixed crop in Jhum cultivation under rain-fed condition and also as monocrop in settled cultivation on hill slopes in Kohima district of Nagaland. (table-1) Kholar (rajmah), field beans (Naga dal), soybean are the predominant pulses in the district and grown as mix or intercrop with maize.

Table-3. Area & production of Major Field crops in Kohima:

Sl.no	Name of crops	Area covered (ha)	Production (in mt)	Productivity (qtls./ha)
1	Paddy (Jhum & TRC)	29311	52760	18
2	Maize	4020	6834	17
3	Mustard	1200	960	8
4	Other seed	1472	1030	7

3. Mokokchung : Three Agro-ecological situations prevailing in the district are as follows:

- ✓ AES 1- Plains below 400 m MSL
- ✓ AES 2- Mid-hill from 400 - 1200 m MSL
- ✓ AES 3- Above 1200 m MSL
- ✓

Table-4. Area & production of Major Field crops in Mokokchung

Sl.no	Name of crops	Area covered (ha)	Production (in mt)	Productivity (qtls./ha)
1	Paddy (Jhum & TRC)	15320	27576	18
2	Maize	1057	1797	17
3	Mustard	1200	1647	6.1

4. Zunheboto. : There are two Agro Ecological Situations prevailing in the district.

- ✓ AES-1 altitude ranging from 600-1500m MSL with sub tropical humid climate
- ✓ AES-2 ranging from 1501m MSL and above with temperate climate.

Agriculture is the main livelihood of the people. *Jhum* cultivation is the major system of cultivation in Zunheboto. Terrace rice cultivation (TRC) is also popular among the farmers.

Cultivation of mixed crop in Jhum is practiced. With less usage of agro-chemicals in crop production the advantage of going for organic farming is suitable and viable. Besides rice, people grow maize, potato, tapioca, oilseed, soya bean, pulses, vegetables and commercial crops.

Table-5. Area & production of Major Field crops in Zunheboto

Sl.no	Name of crops	Area covered (ha)	Production (in mt)	Productivity (qtls./ha)
1	Paddy (Jhum & TRC)	11424	21706	19
2	Maize	7690	13842	18
3	Soybean	2910	2700	9.28
4.	Rajmah	23	23	10

5. Wokha : The three Agro Ecological Situations are:

- ✓ AES-1 It ranges from 110-500m MSL and covers Bhandari, Wozhuro and Ralan block. The average rainfall is about 2000-2500mm per annum. The major crops cultivated are paddy, maize, brinjal, cabbage, cauliflower, tapioca, tea, mango, banana, litchi, coconut. Pisciculture and Animal Husbandry are also found in this situation.
- ✓ AES-2 Ranging from 500-1000m MSL it covers Sanis block only. The major crops grown are paddy, maize, chilly, ginger, yam and a variety of vegetables. Horticultural crops like banana, pineapple, litchi and jack fruit grow abundantly. Farmers also rear animals, poultry and cultivate fish.
- ✓ AES-3 The altitude ranges from 1000-1500m MSL and covers two blocks namely, Wokha and Chukitong. The average rainfall is 2000-2500mm. Major enterprises are agriculture, horticulture and animal husbandry.

Table-6. Area & production of Major Field crops in Wokha

Sl.no	Name of crops	Area covered (ha)	Production (in mt)	Productivity (qtls./ha)
1	Paddy (Jhum & TRC)	18335	36670	20
2	Maize	621	1118	18
3	Soybean	550	550	10
4.	Rajmah	30	30	10
5.	Mustard	830	664	8

Maize - It is extensively cultivated as a mixed crop in Jhum areas under rain-fed conditions and also as monocrop in settled cultivation in some areas.

Millet - Millets is mainly cultivated as a mixed crop in Jhum cultivated areas under rain-fed condition.

6. **MON** : Agro ecological system The district can be divided into 3 AES's.

- ✓ AES-1 ranges from 180m-600m MSL
- ✓ AES-2 ranges from 601m t- 1200m MSL
- ✓ AES-3 ranging from 1201m and above.

- A. Maize - It is extensively cultivated under rain-fed condition as a mono crop in settled cultivation in large areas and also as a mixed crop in Jhum.
- B. Millet is mainly cultivated in Jhum practice under rain-fed conditions as a mono crop in settled cultivation and also as a mixed crop.
- C. Pulse production system- Kholar (Rajmah) is the predominant pulse. It is generally cultivated as a mixed / intercrop crop in *Jhum* with maize

7. **Phek** : Agro Ecological Situation (AES) AES have been identified based on soil . The identified AESs are classified into the homogenous farming situations for the district.

These are namely;

- ✓ AES-I: It is spread over Phek and Kikruma Blocks of the district. The altitude ranges from 900m-1500m MSL. Average annual rainfall is above 1000mm. undulating topography with sandy loam to fine loamy humus soil. Major crops are paddy, potato, temperate fruits, kholar, soybean, floriculture, animal husbandry, paddy cum fish culture.
- ✓ AES-2: It comprises of three blocks namely Pfutsero, Meluri and Sekrezu. The annual rainfall is 1500mm and the soil is sandy to clay loam. Altitude ranges from 1500m-3000m MSL. Major enterprises under this AES are agriculture and animal husbandry. Important crops grown are paddy, maize, ginger, banana, chilly, rice bean, passion fruit, tree tomato. Pig, cattle, mithun, goat, and poultry are the commonly raised livestock

Table-7. Area production and productivity of major field crops in Phek

Sl.no	Name of crops	Area covered (ha)	Production (in mt)	Productivity (qtls./ha)
1	Paddy (Jhum & TRC)	19940	35892	18
2	Maize	8000	13600	17
3	Soybean	6397	1090	14
4.	Rajmah	2700	2430	9
5.	Mustard	270	10	5

8. **Tuensang district** :Agro ecological System (AeS) Considering the altitude as the primary parameter, soil and rainfall as secondary, the district is categorized into two distinct AESs.

- ✓ AES-1: It ranges from low to mid hills of 100m -1500m MSI having warm summer to mid winter cold and high rainfall sub-tropical hill climate. The climatic weather conditions are suitable for agriculture practices. Important major crops such as, paddy, **maize**, sugarcane, sessamum, ginger, colocasia, gourd, pumpkin, chowchow, mustard, chilli, potato, cabbage, banana, orange, pineapple, large cardamom, kiwi, and passion fruit are grown in the district.
- ✓ AES-2: Its altitude is 1500m MSL and above, having cold to extreme cold climate, high rainfall with sub alpine temperature. Crops like paddy, **maize**, millets, jobs- tears bean, kholar, soybean, cabbage, tree tomato, potato, raddish ginger, garlic, pears, plum, large cardamom are grown

Table-8. Area production and productivity of major field crops in Tuensang

Sl.no	Name of crops	Area covered (ha)	Production (in mt)	Productivity (qtls./ha)
1	Paddy (Jhum & TRC)	12930	23274	18
2	Maize	7560	12852	17
3	Soybean	1043	1252	17
4.	Rajmah	3114	3644	9
5.	Mustard	270	10	11.7

9. Peren : The altitude of the district varies from 800m -2500m MSL. Mt. Paona at 2500m, is the highest mountain peak in the district and third highest in Nagaland. Tenning, Jalukie and Peren are the major towns of the district

Table 9. Area production and productivity of major field crops in Peren

Sl.no	Name of crops	Area covered (ha)	Production (in mt)	Productivity (qtls./ha)
1	Paddy (Jhum & TRC)	12100	24926	20.6
2	Maize	1000	1800	18
3	Soybean	68	102	15
4.	Mustard	119	119	1.0

- Maize - It is extensively cultivated as mixed crop in Jhum cultivation under rain-fed condition and also as mono crop in settled cultivation in some area.
- Millet - Millets are mainly cultivated as a mixed crop in Jhum cultivation under rain-fed conditions.
- Pulse production system Pulses such as lentil, green gram, Naga dal and peas are cultivated as mixed or intercrop crop in Jhum.

10. Kiphire: It is headquartered at Kiphire town, which is at an altitude of 896m MSL. The other towns are Seyochung, Sitimi and Pungro. Kiphire has the distinction of having Nagaland's highest peak mount Saramati (3,841m MSL), Fakim Wildlife Sanctuary and the Likhimro Mini Hydro power station.

Table 10 .Area production and productivity of major field crops in Kiphire

Sl.no	Name of crops	Area covered (ha)	Productivity (Mt/ha)	Tatal production in MT
1	Paddy (local)	357	1.8	643
2	Maize	256	1.8	461
3	Kolar (Rajmah)	279	1.1	306.9
4	Soybean	105	-	115.5
5	Total food grain	-		1102.1

11. Longleng: The district covers an area of 885 sq. km. with a population of 1,58,300. Longleng Town is the district head-quarter located at an altitude of 1,066m. MSL. Longleng is inhabited by the Phom Naga tribe spread over 38 villages.

- Maize is grown as major cereal crop after rice in longleng districts of Nagaland.

Conclusion: The status and opportunities for cultivation of maize in Nagaland has vast potentials. However, the hidden potential of maize technology in all districts of the state can be overcome with appropriate climate resilient technologies as given below.

Sl.no	Problems	Technical interventions
1.	Low yield (Average yield 1.7-1.8 t/ha)	Use of composite and hybrid varieties.
2	Use of local varieties	Use of high yielding composite and hybrid varieties.
3	Inadequate plant nutrition	Use of organic manures, bio fertilizers, vermicompost. Popularization of INM
4	Pests and diseases	Adoption of IPM
5	No post-harvest management and value addition	Maize sheller to be provided to the farmer for shelling of maize. Establishment of poultry and cattle feed production units

Tips for Climate Smart Maize Production Technology in Nagaland.

1. Area expansion
2. Introduction of high yielding composite and Hybrid varieties
3. More cultivation under irrigated condition by increasing irrigated area
4. Integrated nutrient management
5. Introduction of location specific intercropping/strip cropping
6. Introduction of suitable varieties for baby corn as high value crop
7. Establishment of cattle/poultry/pig feed production units
8. Introduction of suitable varieties of maize for feed production
9. Integrated pest management

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MAIZE PRODUCTION TECHNOLOGIES FOR INCREASING FARMING RESILIENCY IN MIZORAM

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Maize farming in Mizoram is important because it has a high domestic demand in the state and high export potential. Being a major component of the national food security programme, a large population of marginal farmers in Mizoram are dependent on it. Maize is principally grown in the jhum lands of Mizoram. Local maize landraces dominates over the introduced high yielding varieties, due to local food preference of the tribal communities. These traditional low yielding maize landraces are mixed cropped with a variety of crops (i.e. rice, leafy vegetables, tubers etc) in the jhum lands. Lack of knowledge on suitable crop management practices, technological interventions and deformed market chain often fetches lower farm income to the maize farmers in Mizoram. ICAR Research Complex for NEH region, Mizoram centre has conducted some extensive field scale assessment on the available technological options for rainfed maize cultivation in Mizoram. The details are described below:

1. Crop Diversification: The technological intervention mostly aimed for assuring a minimum level of farm income with subsequent reduction in complete crop failure risk either from weather aberrations or from any other harmful means viz. pest outbreak, during the critical crop growth period in rainfed maize.

a. Maize – pulse/oilseed intercropping: The experiment was aimed to evaluate the water efficient maize-based cropping system in Mizoram. Pulse intercropping was aimed to restore soil fertility and checking soil erosion in the maize based cropping system. Our treatments were comprised of (A) conventional tillage and zero tillage in main plot and (B) intercropping/residue management - maize sole, maize + soybean paired row, maize + ground nut paired row, maize + *in-situ* green manure, in sub plots. We observed that the maize + groundnut paired row recorded maximum Maize Equivalent Yield followed by maize + soybean paired row. The maximum water use efficiency - WUE (42.9 kg/ha-mm) was recorded under maize + groundnut paired row intercropping under zero tillage followed by maize+ soybean (Table 1).

Table 1. Maize equivalent yield and water-use efficiency for different treatment combinations

Treat	Tillage Treatments					
	ZT	CT	Mean	ZT	CT	Mean
	Seed yield (kg/ha)			WUE (kg/ha-mm)		
M1 -Maize sole	5013	4800	4974	30.9	33.1	32.0
M2 -Maize + soybean paired row	5219	5721	5435	36.8	33.2	35.0
M3 -Maize + groundnut paired row	6354	6666	6463	42.9	40.3	41.6
M4 -Maize + green gram	4987	4533	4693	29.2	31.2	30.2



(a) Maize + Soybean



(b) Maize + Groundnut

Fig 1: (a) Maize –soybean (b) maize-groundnut intercropping systems in Mizoram

b. Vegetables - maize intercropping: Vegetable-maize intercropping is widely practiced in the *jhum* areas and upland terrace cultivation system for diversifying farm products and enhancing net farm income in Mizoram. Maize in intercropping combination with upland vegetable like pumpkin, ash gourd, cucumber, tomato and potato was evaluated against the sole maize cultivation during *kharif* season. Ash gourd as intercrop reduced the final grain yield of maize by 30% followed by cucumber (23%); grain yield reduction was 5.19% in tomato followed by 3.45% in potato. Maize is popularly

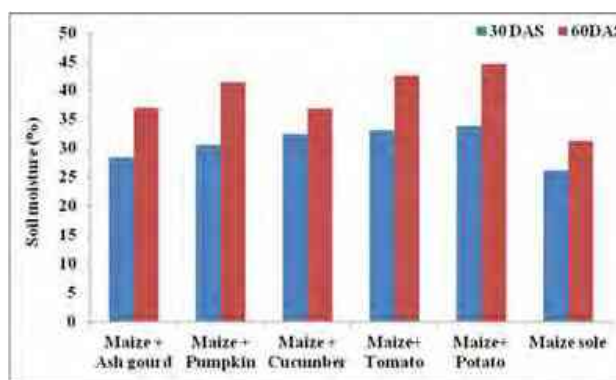


Fig 2: Profile moisture content (%) recorded at 0 - 45 cm under various intercropping options

intercropped with pumpkin in Mizoram preferably due to local food choice for pumpkin at subsistent level. The combination recorded to be the best system in terms of soil moisture conservation due ground cover from the expansive pumpkin canopy (Fig 2) that also increased the grain yield by 8.12% (Table 2a) along with 42% increase in benefit cost ratio (B:C ratio; Table 2b) for the farm household against the sole maize cultivation.

Table 2a. Performance of maize as influenced by intercropping with vegetables.

Treatment	Grains /cob	1000 grain wt. (g)	Grain yield (t/ ha)	Straw yield (t/ ha)	Harvest Index
Maize + ash gourd	379.3	290.5	3.45	5.04	39.4
Maize + pumpkin	388.3	296.4	3.93	5.84	40.2
Maize + cucumber	389.3	305.4	3.77	5.51	40.6
Maize+ potato	405.6	303.1	4.09	6.58	41.2
Maize+ tomato	401.2	305.9	4.12	6.72	42.0
Maize sole	410.0	308.2	4.33	6.35	40.5



Maize-tomato



Maize-pumpkin



Maize-ash gourd

Fig 3: Vegetable-maize intercropping system in jhum lands of Mizoram

Table 2b: Maize equivalent yield, profitability and benefit cost ratio of all combination along with maize in Mizoram

Treatment details	Grain yield (kg/ 0.4 ha)	Maize Equivalent yield (kg/0.4 ha)	Total System Production (kg/0.4 ha)	Gross income (Rs.)	Cost of cultivation (Rs./ 0.4 ha)	Net income (Rs./0.4 ha)	Benefit: cost ratio
Maize + ash gourd	1380	1964	3344	66880	15000	51880	3.46
Maize + pumpkin	1648	2648	4296	85920	15000	70920	4.73
Maize + cucumber	1508	1795	3303	66060	15000	51060	3.40
Maize+ potato	1636	2154	3790	75800	15000	60800	4.05
Maize+ tomato	1572	2851	4423	88460	15000	73460	4.90
Maize sole	1732	0	1732	34640	8000	26640	3.33

c. Residual soil moisture utilization during late monsoon months in the jhum fields



Fig 4: Increasing farm income and managing soil health through introduction of soybean variety JS-355 as second crop after maize

Cultivation of soybean (JS-355) as a second crop after jhum maize (First week of August planting) is efficient to utilize the moisture available from late monsoon season and increase the

and increasing farm income of the tribal farmers. Introducing soybean as 2nd crop could earn an additional net income of Rs. 50,000 per ha with a benefit cost ratio of 2.98:1, for the mizo farmers.

2. Integrated soil health management: To explore the effect of nutrient supplementation effect (fertilization and lime combination) on soil health and rainfed maize yield (variety: RCM-75; during 2016-17 and 2017-18), we laid out a study with 10 treatment combination, arranged in a factorial RCBD. Maize was sown during December and harvested during first week of April. The fertilization treatments include F₀-Absolute control, F₁-NPK half dose, F₂- NPK full dose, F₃- F₁+FYM@ 2.5 t ha⁻¹ and F₄- F₁+vermicompost@ 2.5 t ha⁻¹ and lime treatments include L₀- No Lime and L₁- Lime @ 500 kg ha⁻¹. While there was a poor effect for different dose of fertilizers, lime exerted a significant effect on the soil organic carbon and yield of Maize. Lime application was suitable to improve the soil health and yield of maize which was even upto 50% increase as compare to control; 20 to 30% increase was recorded due to integrated and full dose of nutrient supplementation against control in acidic degraded soil.



Fig 5: Nutrient supplementation trial (lime-fertilizer interaction effect on soil health) in rainfed maize.

3. Introduction Quality Protein Maize (QPMs) seeds: Thirteen maize varieties were evaluated for their yield potential under rainfed upland condition in the experimental farm of ICAR Kolasib. Among the selected varieties three varieties, viz., HQPM, KNMH-408710 and DHM-849 performed significantly better with grain yield of 6.05 t/ha, 5.16 t/ha and 4.84 t/ha., respectively (Table 3). ICAR Kolasib organized Large scale FLD in eight districts of Mizoram covering an area of 534.50 ha under Tribal Sub Plan (TSP) in collaboration with KVKs and District Agriculture Offices of the respective districts. With these interventions, productivity of jhum field increased from 1.5 ton/ha (maize equivalent yield) to 4.6 ton/ha and their net income increased from Rs.30, 400.00 per ha to Rs. 90,000.00 per ha by selling of maize seed. Experiencing the success in high

yielding QPM cultivation, ICAR Mizoram Centre has standardized the package- practices for QPM cultivation and recommended the same to Government of Mizoram under jhum improvement schemes.

Table 3: Performance of different varieties of maize in ICAR farm, Kolasib

Varieties	Cob girth (cm)	Cob length (cm)	Lines per cob	No. of grains per line	Average grain wt (g)	Grain yield (t/ha)
PEEHM 5	14.96	18.60	14.20	34.20	161.60	3.69
HQPM 9	15.99	17.19	15.67	33.13	151.40	3.41
DHM-849	16.36	17.67	15.40	34.87	161.13	5.16
Vivek hybrid 21	15.29	16.25	13.60	32.60	139.73	2.35
Vivek hybrid 23	15.98	19.35	14.00	34.27	169.13	1.77
Vivek hybrid 25	17.45	21.43	15.20	37.80	218.13	4.46
Vivek hybrid 33	16.70	18.63	16.00	36.40	176.60	4.77
Vivek hybrid 39	16.63	20.20	14.93	37.67	195.27	3.98
Vivek hybrid 43	15.91	18.43	13.73	35.87	208.87	3.57
CMH08-156	16.90	20.17	15.87	36.93	195.00	4.61
CMH08-239	16.73	20.53	14.53	37.33	204.13	3.48
HQPM 1	16.93	21.47	15.47	31.13	204.07	6.05
KNMH-408710	16.85	18.55	15.20	34.80	176.00	4.84
Local Mimban	16.45	19.48	15.27	33.40	183.73	1.50



Fig 6: Increasing farm income through Quality Protein Maize in shifting cultivation lands

Finally, wide adaptability of the maize crop ensure the cultivation of this particular crop species to be grown under a variety of climate (sub-tropical to temperate climate) in extensive jhum farming systems of Mizoram. Dissemination of suitable technological interventions through skill development/ programmes are essentially required to increase the rainfed maize productivity and stable farm income for the tribal farmers in Mizoram.

MAIZE DISEASES AND APPROACHES TO THEIR MANAGEMENT IN NEH REGION

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Maize is an important cereal crop in India. It is estimated that by the year 2020, demand for maize in developing countries will surpass demand for both wheat and rice. India ranks fifth in total area and third in production and productivity. In North Eastern Himalayan region of India, maize is the second most important crop, next to rice and mostly grown in rainfed conditions. This level of production has to be substantially raised to meet growing demand of maize for human food, animal and poultry as well as industrial processing by the wet and dry millers to produce value added products. The national average yield of maize is low compared to other leading maize growing countries of the world. Among the factors adversely affecting productivity, ubiquitous prevalence of disease and insect pests in the pre harvest stage are predominant. The total economic loss of the crop in India due to insects and pests in the pre-harvest stage are prominent. The total economic loss of the maize crop in India due to disease and insect pests has been estimated to be of the order of 13.2%. Since there is practically no possibility of increasing maize area, the productivity can only be raised by providing seed of improved cultivars, better agronomic practices and protection against disease and pests.

Maize Diseases and Pests

A. Turcicum Leaf Blight (TLB)

The disease is caused by the fungus *Exserohilum turcicum*. An early symptom is easily recognized, by slightly oval, water-soaked, small spots produced on the leaves. These grow into elongated, spindle-shaped necrotic lesions. They may appear first on lower leaves and increase in number as the plant develops, and can lead to complete burning of the foliage. It has the potential to cause yield reduction up to 70%.



Characteristic symptoms of turcicum leaf blight

Management

- Rotating maize with non-host crops can reduce disease pressure
- Management of overwintering infected crop residue will reduce the amount of available inoculum at the onset of the subsequent growing season

- Fungicide should be applied when lesions first become visible on the lower leaves. Two to four applications of Maneb or Zineb @ 2.5-4.0 gm/litre of water at 7-10 days interval provide good control of the disease

B. Downy Mildews

Downy mildews cause considerable losses to the yield under favourable conditions of fungal growth. These diseases cause severe damage to hybrid maize cultivars. Several mildews are known as mentioned below:

Several species of the genera *Peronosclerospora*, *Sclerospora*, and *Sclerophthora* are responsible for downy mildews: Crazy top downy mildew (*Sclerophthora macrospora*), brown stripe downy mildew (*Sclerophthora rayssiae* var. *zeae*), green ear disease (*Sclerospora graminicola*), Philippine downy mildew (*Peronosclerospora philippinensis*), sugarcane downy mildew (*Peronosclerospora sacchari*) and sorghum downy mildew (*Peronosclerospora sorghi*).

The symptoms appear on younger leaves as white or light green stripes which soon become white or light yellow on most of the leaves of affected plants. The sporangia develop on branched sporangiophores which emerge in groups from the plant tissues through stomata. A white mat of the fungal growth can be seen on the lower or both the surfaces of leaves during wet weather. The stem may also be affected if infection occurs during early stages of plant growth.



Management

- The best control is to use resistant varieties or hybrids, if available
- Spraying with systemic fungicides such as metalaxyl and propamocarb etc. can be used to manage the disease.

C. Maydis Leaf Blight (MLB)

MLB is caused by fungus *Bipolaris maydis*. It has the potential to cause as high as 70% yield loss. Young lesions are small and diamond shaped. As they mature, they elongate. Growth is limited by adjacent veins, so final lesion shape is rectangular and 2 to 3 cm long. Lesions may coalesce, producing a complete burning of large areas of the leaves.



Symptoms of maydis leaf blight

Management

Application of 2-4 sprays of Diathane M-45 or Zineb @ 2.0-2.5 gm/litre of water at 7-10 days interval from the first appearance of disease controls the spread of pathogen.

D. Common Rust

Common rust is caused by *Puccinia sorghi*. The disease is recognised by the abundant oval-elongate, red-brown pustules up to 2 mm long, which erupt through both leaf surfaces in scattered groups. This distinguishes common rust from polysora rust, which has little development of rust pustules on the lower leaf surface. The pustules contain numerous powdery spores that can be spread long distances by wind. Common rust survives between seasons only on living maize plants.



Symptoms of common rust

Management

The only practical control measure is to plant resistant hybrids.

E. Polysora Rust

Polysora rust is caused by the fungus *Puccinia polysora*. Small red-brown or orange pustules develop evenly over the upper leaf surfaces, and larger elongated ones may also develop on the midribs, ear husks and tassels. Polysora rust survives between seasons only on living maize plants. Polysora rust survives between seasons only on living maize plants.



Symptoms of polysora rust

Management

Spray of Diethane M-45 @ 2-2.5 gm/litre at the beginning of appearance of symptoms provides good control.

F. Post Flowering Stalk Rot (PFSR)

It is one of the most destructive diseases and is caused by complex association of multiple pathogens, among which *Fusarium moniliforme*, *Macrophomina phaseolina* and *Cephalosporium maydis* are commonly associated. The symptoms start appearing during senescence and it commonly affects roots, crown region and lower internodes. The disease symptoms manifest after flowering and gets severe under moisture stress/ high soil temperature conditions. Being soil borne, its transmission occurs through contaminated seeds, biological culture, infected crop residue and movement of agricultural equipment.



Symptoms of post flowering stalk rot

Management

- Application of potassium fertilizer minimizes the incidence of disease.
- Avoidance of water stress at flowering stage and crop rotation also reduces the incidence of the disease to a great extent.
- Application of bio-control agent such as *Trichoderma* formulation in furrow @ 10 g/kg of FYM at 10 days prior to sowing provides good control.

G. Bacterial Stalk Rot

Bacterial stalk rot caused by *Erwinia chrysanthemi*. The basal internodes develop soft rot and give a water soaked appearance. A mild sweet fermenting odour accompanies such rotting. Leaves some time show signs of wilting or water loss and affected plants within a few days of infection lodge or topple down. Ears and shank may also show rot. They fail to develop further and the ears hang down simply from the plant



Symptoms of post bacterial stalk rot

Management

- Use of disease resistance varieties, i.e. Hybrids Ganga Safed-2, DHM 103, show significantly less disease incidence than other hybrids.
- Avoid waterlogging and poor drainage.

H. Banded Leaf and Sheath Blight (BLSB)

BLSB caused by *Rhizoctonia solani* f. sp. *sasakii* has recently can cause substantial loss to grain yield and fodder quality. The disease develops on leaves and sheaths and can spread to the ears. Characteristic symptoms include concentric bands and rings on infected leaves and sheaths that are discoloured, brown, tan or grey in colour. Typically, disease develops on the first and second leaf sheath above the ground and eventually spreads to the ear causing ear rot. Ear rot is characterized by light brown, cottony mycelium on the ear and the presence of small, round, black sclerotia (compact mass of hyphae that can survive in unfavourable conditions).



Ears dry prematurely and caking of the ear sheaths is common. Symptoms of banded leaf and sheath blight

Management

- Fields should be well drained prior to planting.
- Treatment of the soil with fungicide prior to planting can reduce survival of the pathogen and reduce disease severity.
- Removing lower 2-3 leaves, application of *Pseudomonas fluorescens* culture @16 g/kg of seeds (as seed treatment) or 7 g/litre of water for soil application coupled with foliar spray of Sheethmar or Validamycin @ 2.5-3.0 ml/litre of water provides reasonable control on the spread of the disease.

I. Maize Streak Disease

Maize streak disease is caused by maize streak virus (MSV). The virus is transmitted by *Cicadulina* spp. leafhoppers'. *Cicadulina mbila* is the most prevalent vector, and transmit the virus for most of its life after feeding on an infected plant. Early disease symptoms begin within a week after infection and consist of very small, round, scattered spots in the youngest leaves. The number of spots increases with plant growth; they enlarge parallel to the leaf veins. Severe infection causes stunting, plant will not develop cobs and plants can die prematurely. Many cereals crops and wild grasses serve as reservoirs of the virus and vectors.



Symptoms of maize streak disease

Management

Cultivars possessing resistance should be planted. Avoid planting before early October or after mid-December. Keep the maize field and surrounding border free of grass and weeds. Remove infected maize stalk from the field or bury burn them. Planting should be done in moist soil that is tilled well to improve uniform germination.

Integrated Disease Management in Maize

Maize diseases constitute an important production constraint because they reduce yield and quality of grain and silage. Downy mildews, Maydis leaf blight and stalk rot are some of the major diseases affecting maize in North Eastern Region of India. An integrated disease management approach using several practices is usually recommended in maize production. Integrated disease management is a knowledge approach for managing diseases by combining compatible cultural, physical, biological and chemical tools in a way that minimize economic, health and environment risk. The most commonly recommended tactics involves the selection of hybrids with genetic resistance to diseases (always opt for hybrid with high yield potential, good resistance to leaf and stalk diseases, and good emergence and seedling vigour traits), application of seed fungicides, the adoption of sound crop management practices which includes rotation with non-host crops of pathogen, cropping sequence, selection of planting site, seedbed preparation, date of planting, varietal maturity and the occasional application of foliar fungicides when warranted by disease risk (field must be scouted regularly to determine if fungicide application is needed and the appropriate time for application).

Cultural Practices

- Crop rotation
- Follow recommended planting dates and plant population.
- Ensure proper drainage for managing stalk rot and avoid moisture stress at flowering stage.
- Fertilize crop as per recommendation.
- Manage the crop residue (plough down or recycling after proper composting).

Genetic Management

Use of resistant/ tolerant hybrids/composites.

Mechanical Control

- Rogue and destroy infected plants.
- Stripping of two lower leaves along with leaf sheath.
- Use bird scarer to prevent seed damage.

Biological and Chemical control

- Seed treatment with thiram 75% WS @ 1.5-2.5 g/kg seed or *Trichoderma harzianum* 2% WP @ 20g/kg seeds
- Add *Trichoderma harzianum* formulation 2% WP in furrow at the time of sowing prior mixing with FYM @10 g/kg FYM
- Spray mancozeb 75% WP @1.5-2 kg/l water or zineb 75%WP @1.5-2 kg/ha after first appearance of disease followed by 2-4 application at 10-15 days interval.
- Soil drenching of bleaching powder containing 33% chlorine @10 kg/ha at pre flowering stage

MAIZE INSECT PEST AND APPROACHES TO THEIR MANAGEMENT IN NEH REGION

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The versatility of maize has always made it a beloved and popular crop among the farmers of NE India. It can be grown in *Kharif* or *rabi* and even during the *zaid* season in a wide range of environmental conditions. It is grown in the valley and foothills and upland *jhum* fields too under varying soil fertility regimes. In some places of the NE hills, maize cobs are harvested and stored before the onset of the cold winter. It is the next important cereal crop after rice in this part of the country. Besides the traditional role that maize has always had in the NE region, its importance and demand is becoming greater in recent times. The development and introduction of HQPM and change in crop diversification favouring intercropping with legumes such as groundnut, cowpea, etc. have brought about a quiet revolution among the farmers, besides increasing yield and soil fertility. Present day use of maize especially HQPM as feed for cattle and poultry industry is going to further encourage the growth of small and medium enterprises in animal husbandry. It will be a win –win situation both for the maize farmers and the cattle/poultry farmers.

However, biotic constraints have always been limiting factors to the cultivation of maize. These biotic constraints are always a factor for reduced productivity in maize. This includes insects, diseases and weeds. Of this, insects are the most notorious constraint causing the most severe damage and as a result, reducing yield substantially. Maize is attacked by 140 different insect species with their different level of damage percentage. Out of 140 species of insect pests, only 12 species are the serious pests of maize causing damage from sowing to the harvesting and also in the storage conditions (Siddiqui and Marwaha, 1993). Maize crop can be attacked at any stage of their life even after harvesting. The severity of pest attack depends upon the cultivars, cultivation practices, mode of storage and environmental conditions (Arabjafari and Jalai, 2007). Insect pest complex in the NE region is also widely different than in other maize growing regions of the country. For e.g. the maize cob borer, *Stenochroia elongella* (Lepidoptera, Pyralidae) the old world webworm which is considered a minor pest in South and North India is a major and dominant pest in this region. Its prevalence and devastating ability is more than even the maize stalk borer, *Chilo partellus* (Lepidoptera, Pyralidae) which is the main insect pest in maize in other parts of the country.

Both borers are the major insect pests causing economic damage in maize in NE India. The pink stem borer, *Sesamia inferens* and maize shoot fly, *Atherigona soccata* although present

in the region is comparatively of lesser importance as a pest due to low incidence (Pathak, 2004).

Defoliators such as tobacco caterpillar (*Spodoptera litura*) and Bihar hairy caterpillar (*Diacrisia obliqua*) are also important insect pest of maize while sucking pests such as aphids, thrips, bugs, leafhoppers etc. are minor pests whose damaging capacity is dependent on favourable weather conditions. Other pests of minor importance recorded on maize include elephant beetle, *Xylotrupes giddeon*, grasshoppers, *Aularchis meliaris*, *Chrotogonus sp.*, *Hieroglyphus nigrorepletus*, semilooper, *Trichoplusia orichalcea*, termites (*Odontotermes sp.*), cutworms (*Agrotis spp.*) (Pathak, 2004; Shylesha *et al*, 2006; Azad Thakur *et al*, 2009). Upland maize or maize grown on foothills is also infested by white grubs too.

Under prevailing climate change regimes, the damage due to insect pests are bound to increase as a result of increased temperature favouring these insects.

A. MAJOR PESTS

1. Maize Cob borer or Sorghum earhead caterpillar, *Stenochroia elongella* Hampson

This pyralid insect can be considered to be most important insect pest of maize in the NE region, ahead of another well-known cob borer i.e. *Helicoverpa armigera*. In this region, the importance of *Helicoverpa armigera* as a cob borer is not as dominating as in other parts of the country.

The adult moths of *Stenochroia elongella* emerge after mid-June and egg laying starts on growing corn cobs. About 60-70 eggs are laid singly on the cobs between two cob sheaths. Eggs are small cream coloured and hatches in 5-8 days. The caterpillar on hatching bore into the corn cobs and create characteristic punctured holes on the corn cobs. There excrements coming out from these holes along with the punctured holes are the characteristic symptoms of the cob borer damage. Presence of 3-5 borers in a single cob can completely damage the cob. The puncture holes and their excrements also leads to the secondary infection by fungus. There were found to be four larval instars over a period of 28-30 days. Pupal duration was observed to be about 6-7 days and found to occur within the cob or between cob sheaths. Three to four overlapping generations from July to end of September were recorded (Pathak, 2004).

As is observed in borers, late sown crop suffers more damage than early sown crop. The adult moths prefer sorghum crop to maize for oviposition and sorghum can be used as a trap crop to lure away the adult moths.

2. Maize stalk/stem borer, *Chilo partellus* (Swinhoe)

Another major pest of maize in the region is the maize stem borer. It is devastating because it can affect the crop in early stages and destroy the crop completely if not controlled. In different agro-climatic regions of India, *C. partellus* has caused damage of

26.7-80.4% to sorghum (Sethuraman and Narayanan, 2010). It is the principal pest in lowland areas (Yonow *et al*, 2017).

After hatching, the young larvae crawl and feeds on tender folded leaves causing typical “**shot hole**” symptom. Then, larvae mines the midrib enter the stem and feeds on the internal tissues.

Bore holes are visible on the stem near the nodes. During the vegetative stage, it causes “**dead heart**” where the central portion of the growing shoot is killed and as a result the whole plant dies. Affected parts of stem may show internally tunnelling caterpillars.



Puncture holes of
cob borer



Cob borer caterpillars
feeding on maize cob



Characteristic symptom of
maize stalk borer with shot



Newly hatched stem borer
larvae scarring on leaf



Shot holes on leaf



Dead heart of central shoot



Important green pesticides for managing insect pests

B. MINOR PESTS

3. Maize shoot fly/ stem fly, *Atherigona soccata* Rondani

The insect attacks the young crop when it is in the six leaf stage. Six weeks after planting, the crop is seldom attacked. Maggots are cylindrical, tapering towards head, pale yellow or dirty white in colour. The adults are dark grey coloured, housefly-like but much smaller flies (5 mm long). As the maggots feed on the main shoot, the growing point is destroyed and by the time they pupate, the plant is almost dead. They feed inside the main shoot for 6-10 days and, when full grown, they may pupate either inside the stem or come out and pupate in the soil. The young plants show typical dead-heart symptoms. The total loss in yield is sometimes as high as 60 per cent. Cloudy weather favours the multiplication of this insect and it is believed that infestation is also higher in irrigated fields. The high-yielding hybrids are more susceptible to the attack of this fly.



Maize Shoot Fly Adult And Its Damage Symptom

4. Maize Aphid, *Rhopalosiphum maidis* Fitch

Maize aphids are oval-shaped, with soft bodies and a pair of cornicles protruding from the end of their abdomen. They are olive green to bluish-green in colour, and have short

antennae and dark legs. Both winged and wingless forms occur. Both apterus and pterous aphids infest the upper half of the plant. Nymphs and adults suck the sap from the leaves / shoots and exude honeydew, on which a sooty mould grows, giving the leaves a black appearance and thus affect photosynthesis badly resulting in yellowing of leaves.



Aphids and their damage symptoms on maize

INTEGRATED PEST MANAGEMENT IN MAIZE

Cultural practices

- i. Deep summer ploughing and leave the field to expose to hot sunshine to kill the resting stages of pests and to destroy the stubbles and perennial weeds by allowing farm animals to graze on it to destroy overwintering larvae.
- ii. Timely sowing of crop and maintain proper spacing
- iii. Intercrop with legumes like soybean, cowpea and green gram to reduce the incidence of borer.
- iv. Balanced use of manures and fertilizers to reduce pests' infestation.
- v. Proper irrigation management and avoidance of moisture stress at the time of flowering to grain filling stage.
- vi. Planting Sorghum as a trap crop for managing cob borer.

Genetic Management

- i. Use certified seeds of recommended varieties

Mechanical Practices

- i. Manual weeding at 2-3 and 6 weeks to prevent the shelter of insect pests.
- ii. Removal of dead hearts and diseased plants or alternate hosts will help to reduce second generation infestation.
- iii. Use of bird scarer prevents seed damage.

- iv. Manual collection and destruction of white grubs and chaffer beetle during adult emergence period reduces the pest population.
- v. Use of pheromone traps from one-month crop stage @ 4–6/acre to control pest at early stage.
- vi. Installation of light trap to attract adult moths @1 trap /acre for monitoring and mass trapping.
- vii. Stripping of two to four lower leaves along with leaf sheath to reduce oviposition of maize stem borer.

Biocontrol and Chemical control

- i. Seed treatment with imidacloprid 70 WS 10 g/kg of seeds. Farmers following organic practice/farming can use *Trichoderma viride* or *T. harzianum* for seed treatment @2ml/litre of water (for 1 acre) and soak the seeds in this solution for 30 minutes, shade dry the seeds and sow them.
- ii. Soil application of phorate 10%CG @ 10 kg/ha at the time of sowing
- iii. Spray the crop 2-3 weeks after sowing as soon as borer injury to the leaves is noticed with *Bacillus thuringiensis* var. *Kurstaki* @ 1.5 kg/ha (5ml/litre) or application of *HaNPV* @ 500 ml/ha (250 LE) with adjuvant like teepol, jaggery, tinopal or Coragen 18.5 SC (chlorantraniliprole) @ 30 ml or deltamethrin 2.8 EC @ 80 ml using 60 litres water per acre with knap-sack sprayer.
- iv. For sucking insect pests, spray oxydemeton methyl or dimethoate 30EC @ 200 ml per acre in 50 litres of water with manually operated knap-sack sprayer.
- v. Spraying of Neem pesticides @ 3ml/ litre or annonin extract @2ml/litre at silking stage effectively helps to reduce cob borer population
- vi. Whorl application of Carbaryl 3G or Phorate 10G @ 2-3 granules per whorl at 28-30 days after germination effectively kills the borers and cutworms.
- vii. The hairy caterpillars can be destroyed by crushing the grown up caterpillars under feet or by picking and putting them into kerosenized water. If the population is high, control it by spraying 500 ml of Quinalphos per acre in 100 litres of water with a manually operated knap-sack sprayer.
- viii. Farmers following organic farming/practice can use *Beauveria bassiana* @5ml/litre water for managing lepidopteran caterpillars and even sucking pests too. The common trademark name of *B. bassiana* is Green Racer.
- ix. For termites and white grub infestation, frequent irrigation before land preparation and during the crop growth reduces its infestation. Application of Fipronil granules @ 20kg/ha followed by light irrigation controls soil insects to some extent. Farmers following organic farming/practice can use *Metarhizium anisopliae*@ 5ml/litre for

foliar application and soil drenching around the root zone. However, in case of termite infestation, destroy the termitarium first and it should be used at 10ml/litre and applied liberally in and around the termitarium. The common tradenames of *M. anisopliae* is Green Muscle or Green Pacer.

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