Vision 2030

Directorate of Soybean Research

Indore

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Vision 2030

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(भारतीय कृषि अनुसंधान परिषद्)
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SECRETARY & DIRECTOR GENERAL

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Foreword

The diverse challenges and constraints as growing population, increasing food, feed and fodder needs, natural resource degradation, climate change, new parasites, slow growth in farm income and new global trade regulations demand a paradigm shift in formulating and implementing the agricultural research programmes. The emerging scenario necessitates the institutions of ICAR to have perspective vision which could be translated through proactive, novel and innovative research approach based on cutting edge science. In this endeavour, all of the institutions of ICAR, have revised and prepared respective Vision-2030 documents highlighting the issues and strategies relevant for the next twenty years.

Soybean has become the most important oilseed crop of India in terms of both area and production and is significantly contributing to country's edible economy. Mercurial rise of soybean on country's edible oil horizon is not without its share of woes. Climate change and its numerous inadvertent effects along with plethora of other biotic and abiotidc stresses pose a major challenge to the researchers for taking soybean to the new heights. Near stagnant productivity levels with persistent adoption gaps are the serious challenges looming large over the forward march of soybean. Times are ripe when we have to think apart from solely export driven soybean economy to the one that has strong roots in our own market also. Promotion of soybean for alternative uses or speciality traits could be a torch bearer for this long journey ahead. The

Directorate of Soybean Research (DSR), Indore has prepared a road-map for productivity improvement and promoting diversified uses of soybean for the benefit of soybean farmers in the country.

It is expected that the analytical approach and forward looking concepts presented in the '*Vision 2030*' document will prove useful for the researchers, policymakers, and stakeholders to address the future challenges for growth and development of the agricultural sector and ensure food and income security with a human touch.

Dated the 24th June, 2011
New Delhi

(S. Ayyappan)

Preface

The Directorate of Soybean Research (DSR) is a premier institution engaged in soybean research and development in the country. It was established in 1987 under aegis of Indian Council of Agricultural Research (ICAR) to provide centralized support to the production system research with basic technologies and breeding material of soybean. It also looks after the inter-disciplinary and multi-location research through All India Coordinated Research project on Soybean. The comprehensive initiatives taken by DSR along with all the stakeholders have led to unprecedented growth in area, production and productivity of soybean in the country. Today soybean is the most important oilseed crop with substantial contribution to edible oil pool and foreign exchange earnings for the country. With the rapid expansion of the crop, the dynamic technological backup in terms of soybean varieties, improved production technologies, their dissemination and quality seeds was duly provided by DSR.

New challenges that soybean would possibly face in next two decades to come would be of altogether different nature and humungous proportions. Research technologies would require concerted efforts from all the stake holders. Genetical, production and protection technologies have to re-align themselves with new climatic trends and market realities and demands. There would be added dimensions to research-clientele interface. The Vision 2030 articulates the strategies to overcome these challenges and would go a long way in helping researchers, policy makers, industry and other stake holders to tackle these issues in holistic and participatory manner

I would like to express my gratitude to Dr. S. Ayyappan, Hon'ble Secretary DARE and Director General, ICAR for his valuable guidance in preparing DSR Vision 2030. The valuable suggestions made by Dr. S. Dutta, Deputy Director General (Crop Sciences) and Dr. B.B. Singh, Assistant Director General (O&P) are duly acknowledged.

I appreciate the efforts of Dr. V.S. Bhatia, Dinesh K. Agarwal and all the staff members of DSR in bringing out this document. I am sure DSR 2030 would provide a roadmap for future R & D of soybean in the country.

June 30, 2011

(S.K. Srivastava)
Director
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Preamble

Soybean is the most important oilseed crop of India. Besides contributing significantly to the edible oil pool, it earns considerable amount of foreign exchange for the country. Within four decades of its introduction to central and southern parts of the country, it has made significant inroads among agrarian community. There are very few examples of any other crop taking such giant strides in terms of adoption among farmers, as soybean has achieved. Owing to its oil and protein profile, this crop has an important role in nutritional security of masses. Soybean has largely been responsible in uplifting farmers' economic status in many pockets of the country for the higher prices it fetches in the market owing to the huge export market for soybean de-oiled cake. Soybean could make such an unparallel progress because of intense efforts of farmers and researchers alike. So far, Directorate of Soybean Research and its AICRPS allies have lived up to expectations in terms of making available high yielding varieties, matching crop production technologies, efficient plant protection modules and effectively transferring these technologies to the farmers.

The challenges that lie ahead in the future are of altogether unprecedented nature. Notwithstanding the spectacular growth in terms of area expansion and production over the last four decades, near stagnant productivity levels with large adoption gaps, climate change and altered biotic and abiotic pressures pose a major challenge to the researchers for taking soybean to new heights. Already effects of climate change are being witnessed in many parts of the country, which are only going to get intensified in the time to come. This would necessitate a major realignment in entire soybean production regime comprising all the constituent technologies. Future market requirements and compulsions of domestic and export soybean economy would also be factors that would determine

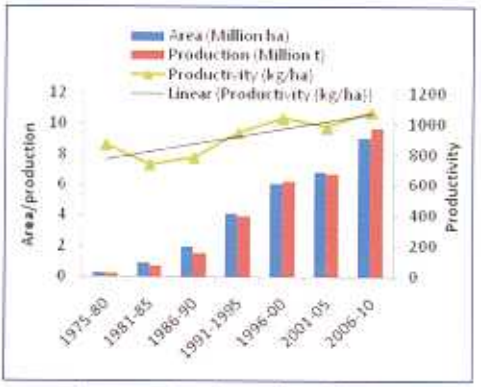
the course and pace of soybean farming and research. Vision 2030 for soybean at the behest of Indian Council of Agricultural Research, New Delhi is such an effort to spell out the technology gaps and their redressal through innovative research approaches. It is hoped that it would provide a direction to researchers and policy planners for moulding their research and planning priorities in tune with the needs of farming community and industry in the next 20 years.

Contents

Soybean Scenario

SOYBEAN [*Glycine max* (L.) Merril] is the world's most important seed legume which contributes 25% to the global edible oil, about two thirds of the world's protein concentrate for livestock feeding and is a valuable ingredient in formulated feeds for poultry and fish. India ranks fourth in terms of soybean area in the world behind only to USA, Brazil, and Argentina. However, in terms of total production, India ranks fifth in the world after USA, Brazil, Argentina and China. The contribution of India in the world soybean area is 10% but the contribution to total world soybean production is only 4% indicating its relatively lower levels of productivity (1.1 t/ha) as compared to the world average (2.2 t/ha), which is a major cause of concern.

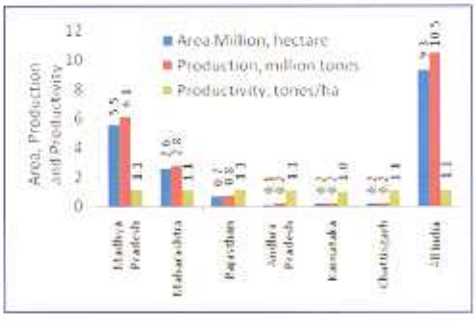
The commercial cultivation of soybean crop in India commenced in late sixties. Thereafter, it has made an unprecedented phenomenal growth, having no parallel in the crop history world over. Starting from an area of just 30,000 ha in 1970, soybean has reached to 9.21 million ha in 2010. The production and productivity levels of 14000 tones and 0.43 t/ha in 1970 have increased to 10.4 million tones and 1.2 t/ha in 2010, respectively. Due to rapid expansion, crop surpassed area and production of rest of the oilseeds in 2006-07 and since then has acquired number one position among the oilseed crops of the country. Soybean is predominantly grown as rainfed crop in Vertisols and associated soils with an average crop season rainfall of 900 mm which varies greatly across locations and years. Introduction of soybean in these areas has led to a shift in cropping system from rainy season fallow followed by post rainy season wheat or chickpea (fallow-wheat/chickpea) system to soybean followed by



Area, production and productivity trend of soybean in India

wheat or chickpea (soybean-wheat/chickpea) system. This has enhanced the cropping intensity entailing into increased profitability per unit land area. Introduction of soybean has helped in improving the socio-economic conditions of large number of small and marginal farmers, probably due to the fact that even under minimum agricultural inputs / management practices, and climatic adversities, it fetches profitable returns to the farmers. In fact, soybean has emerged as one of the most resilient rainfed *kharif* season crops, as despite aberrant weather conditions in recent past, the crop has maintained a considerably good level of productivity.

The area under soybean is mainly spread in latitudinal belt of about 15 to 25 °N comprising the states of Madhya Pradesh, Maharashtra, Rajasthan, Chhattisgarh, Andhra Pradesh and Karnataka. These states together contribute to about 98% of the total soybean production in the country. In recent years soybean is rapidly spreading in southern parts of the country. Since beginning, Madhya Pradesh has been the major contributor and is currently contributing 59% of area and production followed by Maharashtra with figures of 28 and 26% to the total area and production of the country. The crop can be grown in most parts of India and North Eastern states, Himachal Pradesh, Gujarat and Jharkhand have good potential of soybean. However, proper procurement, marketing and industrial support are to be ensured in newer areas.

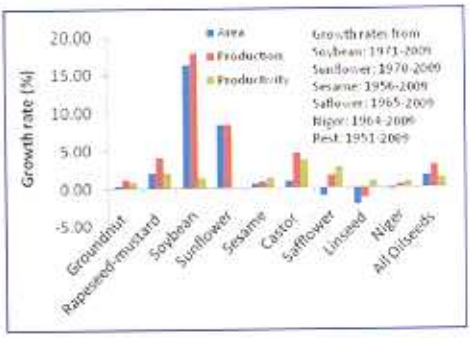


Major soybean growing states

Contribution of soybean to edible oil economy

India has the fifth largest vegetable oil economy in the world. After cereals, oilseeds are the second largest agricultural commodity, accounting for the 14% of the gross cropped area in the country. However, the country is meeting its edible oil demand by importing almost 50% of its requirement. The per capita consumption of the vegetable oil is increasing very rapidly due to increase in population and improved economic status of the population. The demand has increased to about 12.6 kg/year

compared to 4 kg/year in 1961 and the projected demand for the year 2015, 2020, 2025 and 2030 is 14.72, 16.38, 17.92 and 20.17 kg/year respectively. To meet this demand, the country will require nearly 18.46, 21.72, 24.89 and 29.33 million tons of edible oil with commensurating figures of 41.64, 48.87, 56.0 and 65.99 million tons of oilseeds. In this scenario, soybean has played and will play pivotal role in future in meeting these demands.



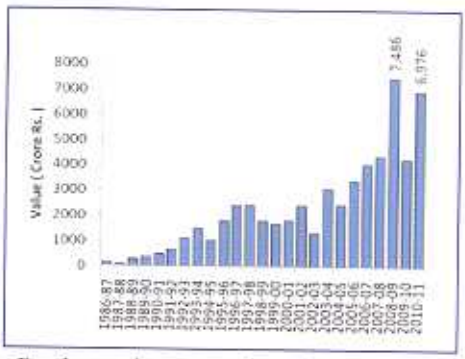
Growth rates of nine oilseed crops in India

On an average the growth rates in area production and productivity of the major nine oil seeds crops in India has been 1.59, 3.03 and 1.42 % respectively. The contribution of soybean in growth of area (16.32%) and production (17.91%) has been phenomenal, as compared to rest of the oilseed crops, indicating that the crop has played a key role in increased production of oilseeds and in meeting the edible oil requirements in the country. The soybean started contributing to total oilseeds production from 1970 onwards. By 1985-86, when Technology Mission was launched to promote oilseeds production, soybean's share was 9.4 per cent. The impact of Technology Mission was discernable and after a decade in 1995-96 the oilseed production reached to more than double (22.11 million tons) over that of 1985-86 (10.83 million tons). Currently, total oilseeds production has reached to 27.8 million tones. Soybean contributes 35% and 25% respectively to the total oilseeds and edible oil produced in the country. The contribution of soybean is estimated to reach to 40 per cent by 2025 as per the projections made based on the growth rates over past period.

Soybean : A major foreign exchange earner

Soybean has remained a key foreign exchange earner due to export of soybean de-oil cake (DOC). Soybean DOC export was ₹ 132 crores in 1986-87, which increased to ₹ 7485 crores by 2008-09. The total expenditure on import of edible oil was offset to the tune of more than 60% by the export earnings of soya- meal. In fact, besides others, the high lucrative market price had been one of the main factors for such a

spectacular success of soybean venture in India. Since beginning of the commercial cultivation, the soybean economy has mainly been governed / dependent on the export of defatted soybean oil cake. The market prices of soybean had always been much higher than the minimum support price declared by the government due to better prices fetched by Indian DOC in international markets. However, these prices have fluctuated a great deal due to ups and downs in international prices of DOC and total dependency of soybean venture in India on export of DOC is a major cause of concern. However, in recent past there has been an increasing trend in domestic consumption of soybean DOC in the country. Soybean being an international commodity and USA, Brazil and Argentina being big players, the dependency of soybean in India on DOC export can threaten its cultivation in India. Therefore, there is an urgent need to increase the domestic consumption of soybean / DOC so as to minimize the dependency on international markets.



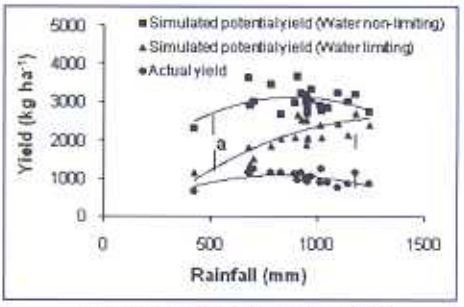
Foreign exchange earnings from soy meal

Soybean as an instrument for protein-energy mal nutrition alleviation

The unique chemical composition of soybean seed which includes about 20% oil and 40% protein besides number of nutraceutical compounds such as isoflavons, tocopherol and lecithin has made it one of the most valuable agronomic crops in the world. The food derived from soybeans are generally considered to provide both specific and general health benefits and being a cheaper source of high quality protein, the crop has a potential to alleviate large scale protein malnutrition prevailing in poor section of society in the country. Although, the county is earning huge amount of foreign exchange through the export of soy meal, but it is on the cost of draining out the valuable high quality protein from the country. Currently, the utilization of soybean for food uses in India is meager. If the high quality soybean protein is included in daily diet of Indian masses, it can help in mitigating the wide spread energy-protein malnutrition. Already the Government of India as well as private sector have taken initiatives to increase the food use of soybean in the country.

Potential yields and yield gaps of soybean

The productivity of soybean in India though has increased from 426 kg/ha in 1970-71 to 1120 kg/ha in 2010-11, but is still much below the potential of the crop in India. Thus, the poor productivity of crop and great fluctuation in it has been the major cause of concern in India. Simulation studies carried out across India have revealed that the climatic potential of the crop is 3000 to 3500 kg/ha while rainfed potential is 2000 to 2500 kg/ha as against national average of 1100 kg/ha. The average rainfed potential of 2000 kg/ha has also been demonstrated in large number of on-farm trials conducted over years across India. Several abiotic, biotic and socio- economic factors, responsible for poor productivity of soybean in India have been identified. However, the major cause of large yield gaps between rainfed yield potential and actual yields harvested by farmers is attributed to non-adoption of improved production technology by the farmers.



Potential yields and yield gaps of soybean in India

Soybean Research and Development System

TO enhance the oilseed and pulse production and ensure the availability of edible oil and pulses at reasonable prices, the government of India has been consistently making efforts to gear up their research and development programmes through TMO (1986), TMOPM (1991) and 2004 onwards through ISOPOM programmes. In India the soybean R & D set up had always been ahead of its time. The ICAR started the All India Coordinated Research Project on Soybean (AICRPS) in 1967 when hardly any area of significance was under the crop. Eventually, ICAR established the National Research Centre for Soybean (now upgraded to Directorate of Soybean Research during XIth Plan) at Indore in Central India in 1987 when soybean covered only about 1.5 million hectares, nearly one-sixth of the present coverage by the crop. At present, it has surpassed groundnut and rapeseed / mustard in cultivable area and production, the two most important edible oilseeds among nine oilseeds grown in the country.

The soybean research in India is being pursued by Directorate of Soybean Research (DSR) and All India Coordinated Research Project on Soybean (AICRPS). The AICRPS is an integral part of the DSR with 8 main, 14 sub and 16 need based centers, spread across the nation. The system is well equipped with human resource, equipments and infrastructure to conduct quality research. Through their unified efforts and support from soybean industry, non-governmental organizations and farmers, soybean is playing a pivotal role in oil economy of the country. The advancement in research component culminating to improved varieties and agro-ecological zone specific production technologies has been a driving force in motivating the other components of production system to function in harmony leading to unparallel growth of the crop and elevated socio-economic status of small and marginal farmers.

Mandate

- To serve as National Repository of soybean germplasm and its utilization in basic, strategic and applied research.
- To conduct basic, strategic and applied research on environmentally eco-friendly technologies and value addition.
- To coordinate multi location interdisciplinary soybean research through AICRP for soybean.
- To facilitate transfer of research emanated technologies and to conduct impact analysis through socio-economic research.
- To produce breeder seed of improved varieties of soybean

DSR 2030

THE Directorate of Soybean Research is making all out efforts with renewed vigour to face the challenges of making country self sufficient in edible oil through increased production and productivity of soybean and to improve the socio-economic conditions of large number of small and marginal farmers dependent on soybean for their livelihood. The efforts would be to take along all the stakeholders including soybean industry, NGOs and farmers and develop the technologies which cater to the current as well as future needs of each stakeholder and to make soybean cultivation sustainable and globally competitive.

Vision

To contribute to edible oil pool and energy-protein malnutrition eradication programme of the country.

Mission

To enhance and sustain soybean production and productivity.

Focus

To attend the goals of enhanced soybean production and productivity along with the associated mission objectives of bolstering Indian farmers' economic status and eradication of maladies of protein-energy malnutrition, the concerted strategies have been formulated to focus on following areas.

- Impact assessment and development of management strategies for current and future climate variability in soybean in terms of responsive varieties, production and protection technologies including suitable farm machinery and quality traits matching future consumer preferences.
- Enhancement of genetic resources and evaluation for desirable traits to combat the emerging problems.
- Crop improvement using functional genomics, MAS, transgenic and allele mining approaches

- New strategies like exploring the possibility of harnessing hybrid vigour and accumulation of yield related QTLs to overcome genetic yield barriers
- Development of specialty soybeans for increased food uses and industrial exploitation
- To develop sustainable organic farming in specific areas/regions to cater to the needs of premium local and foreign markets
- Management of biotic and abiotic stress scenario
- To facilitate knowledge imbibition amidst clientele trough aggressive and efficient extension tools
- To promote and develop technology for soybean based secondary agriculture
- Institutional capacity building through intensive HRD to meet the future research challenges

Soybean : Challenges and Strategies

THE Directorate of Soybean Research right from its inception has been involved in promotion of soybean in the country. Despite having already made giant leaps in both area and production of soybean in the country, it would continue to strive for increasing productivity, enhancing input use efficiency, reducing cost and post-harvest losses, minimizing risks and improving quality of end use commodity through conventional techniques as well as new science and tools. To achieve these goals, the DSR would bring together all the stake holders including All India Coordinated Research Project on Soybean, NGOs, private sector and the farmers on a common platform.

In the present context there is a tremendous strain on our foreign reserves on account of ever increasing import bill of edible oil. In the situation that has been made still more complicated by the new climatic and market challenges on domestic soybean production system, the refinement and re-alignment of research technology has assumed a key role as experienced never before. To ease the edible oil scenario in the country, soybean has in past played a key role and to further increase its contribution to edible oil pool, DSR will strive using new tools, methods, techniques and approaches that promise technological breakthroughs to accomplish the mission.

Enhancement of genetic resources

The plant genetic resources (PGR) are the building blocks of crop improvement for meeting the present and future agrarian needs. Directorate of Soybean Research is a National Active Germplasm Site (NAGS) for Soybean. It is also the National Repository of soybean varieties and germplasm. The genetic resources of soybean have been extensively augmented, evaluated and documented since the start of the project and the total collection now stands at 4180 accessions of cultivated soybean, 36 accessions of wild relative belonging to GP-3 and annual wild progenitor of cultigen of *Glycine soja*. To address research requirements of the future, DSR will facilitate use and consolidation of available genetic resources by (i) enrichment of soybean genetic resources through import/exchange of trait specific soybean accessions from large sources like USDA (USA), AVRDC

(Taiwan) and China, (ii) molecular characterization and gene flagging, (iii) broadening the genetic base through genetic enhancement and pre breeding, (iv) functional genomics, proteomics, phenomics etc., as add-ons to their genetic worth and (v) gene tilling and utilization of chip technology.

Genetic improvement

Soybean is a short day plant and is highly sensitive to day length. This results in narrow adaptability of individual soybean varieties across latitudes and planting times. Since 1970s when the commercial cultivation of soybean began in India, 98 soybean varieties have been released for cultivation in different agro-ecological zones of the country. Till 1980, most of the varieties were either introductions or selections from exotic material. These have been called as varieties of 'Selection cycle-1". During 1981-90, exotic varieties were used as parents to generate new variability for selection.

JS 97-52: High yielding soybean variety

The varieties developed since 1990 have been grouped in 'Selection cycle-2'. The varieties of selection cycle-1 have produced 4 times higher yield than indigenous variety 'Kalitur' by virtue of high number of pods per plant and seed weight, short duration and increased biomass. The varieties in selection cycle-2 showed 19% higher yield than selection cycle-1 varieties. This was due to improvement in harvest index and seed filling duration.

The further genetic enhancement of yield in soybean and its stability under rainfed condition is of utmost importance. The ideal soybean plant for high yield should have determinate or semi determinate growth habit (suited to short growing season), erect and non lodging, rapid LAI development and seed fill duration, and maturity duration of 95-100 days. Besides yield, the other essential characters required for

Transgenic in soybean

soybean in tropics are resistance to pod shattering and good seed longevity. The major biotic stresses which reduce soybean productivity under Indian conditions are diseases like yellow mosaic virus, rust, rhizoctonia, anthracnose etc. and insect-pests like stem fly, girdle beetle and various defoliators. Being a rainfed crop, drought is a major abiotic stress which limits the productivity of soybean in India. Therefore, tolerance to drought is one of the major areas where the breeding programme would be focused. Looking at the future climate change, the breeding programmes would also focus on development of varieties with tolerance to high temperature conditions and better response to alleviated levels of CO_2. Early maturity is an important breeding objective, first to fit it in the multi crop situation and secondly to escape moisture stress in late season. Keeping in mind the depleting stock of available phosphorous and micro-nutrients in soils world over, the future breeding programmes need to be oriented towards development of varieties with better nutrient use and extraction efficiency. Besides the conventional breeding approaches, new tools of molecular breeding such as allele mining, marker aided selection, functional genomics, genetic engineering (transgenics) and exploiting hybrid vigour will be pursued.

Improved production technologies

Region specific crop production technology module have been developed and advocated successfully by DSR. To maintain the remunerability of soybean to Indian farmers and also to upkeep its global competitiveness, its productivity levels have to climb up to new heights.

Soybean planted on Ridges-furrow system

Looming climatic changes, shift in cropping patterns along with the advent of new genetic technologies with remarkable yield potentials would pose a major challenge to soybean production system to march along. New production system technologies have to be developed with inbuilt flexibility to compensate for unpredictable climatic aberrations, adaptiveness to integrate with any shifts in cropping patterns and ability to respond to new genetic technology syngerstically. Therefore, there is a need to refine current production technologies and develop new technologies which can lead to enhanced productivity at reduced cost of cultivation so as to add to farmers income.

In situ moisture conservation, optimization of cultural practices, weed and nutrient management and mechanized farm operations would draw the broad outline of soybean farming in 2030. The availability of soil moisture is a major limiting factor for crop production in rainfed environment and planting of soybean on broad bed furrow and/or ridges and furrow system in Vertisols under real farm conditions helps preventing ill effects of moisture deficit and excesses and helps in yield enhancement in soybean as well as of soybean-wheat system. To create such land configurations along with planting of soybean, DSR has developed BBF (Broad Bed and Furrow) planter and Ridge and furrow system (FIRBS) and would be working on further refinement and cost reduction of these machines to make it affordable to small and marginal farmers.

BBF - Seed drill for soybean

Risk aversion is an important management strategy in rainfed farming. Soybean fits well in intercropping with many crops in highly unpredicted environment of rainfed agriculture. Intercropping of soybean with pigeon pea, maize and sorghum under rainfed conditions has been proven as remunerative technology and future approaches would continue on identification of more profitable new crop/variety combinations for existing areas and new niches. For judicious and efficient use of genetic and natural resources (soil and water),

improvement of water and nutrient use efficiency and minimization of external inputs for sustainable and improved productivity of soybean are the key areas of conservation agriculture. At present, research work on conservation agriculture has been carried out at DSR and future focus would be on sustainable soybean production through crop rotation and tillage systems, soil moisture and nutrient management for sustainable soybean-wheat and other area specific cropping systems, harnessing potential microbial community, evaluating potential of naturally occurring bio-control agents of soybean insect-pests and insecticidal properties of some plants against polyphagous pest, Spodoptera litura.

Harnessing microbial community

Soybean being a legume harbors a number of agriculturally important microbes that help in fixing atmospheric nitrogen and also help in solubilizing soil phosphorus and zinc and making them available to the plants. DSR has identified strains of Rhizobia which can tolerate high temperature conditions and other bacteria such as *Bacillus* and Pseudomonads with plant growth promoting properties. Similarly, Arbuscular mycorrhizal fungi (AMF) are known to enhance carbon sink in the below ground through aggregation of soil particles which also help in mitigating adverse impact of drought and other abiotic stresses, and enhancement of phosphorus nutrition in crop plants. Considerable work on these aspects is being carried out at DSR and efforts would continue to refine these production technologies to render them more cost effective and eco-friendly to suit different level of farmers. In tune with conservation agriculture, further work on harnessing native/resident AMF and Rhizobial population for enhanced productivity of soybean and bioprospecting of *Bacillus* and *Pseudomonas* species in vertisols of central India under soybean cultivation would also be taken up.

Double zinc solubilization halo zone produced by Pseudomonas

Organic farming

Lately there is an emerging trend for organic food in domestic as well as international markets as it often fetches a premium price. To capitalize on emerging market both nationally and internationally many governments of soybean growing states are emphasizing/promoting organic farming. The biggest challenge for organic farmers is to achieve and then to sustain the higher yield levels of crop. Future research efforts would be directed on assimilating the production dynamics under organic farming so as to develop suitable technological interventions to sustainably enhance yield levels under organic inputs. Future crop production technology would have to be custom built to commensurate with the needs of organic farming and reigning consumer preferences.

Mitigating biotic stresses

Like other crops of Kharif season, soybean also has to compete against a number of biotic stresses. Among thirty-five reported diseases of soybean, 20 are considered as major diseases, eight are pandemic in prevalence while others are restricted to certain regions only. Annual yield losses from diseases in soybean are in the tune of 12% of the total production. Diseases viz. yellow mosaic, soybean mosaic, Indian bud blight, rust, anthracnose & pod blight, Cercospora blight (Purple seed stain), Sclerotium blight, Rhizoctonia root rot, aerial blight and bacterial pustule occur regularly with wide distribution. In recent years rust, charcoal rot, fungal complex, yellow mosaic, Indian bud blight and no-podding syndrome have assumed importance. DSR has successfully been able to provide and recommend a basket of technologies including resistant varieties, seed and soil treatments, fungicidal sprays and compatible bio-control measures to mitigate these biotic stresses.

YMV infested soybean

Girdle beetle (*Oberiopsis brevis*), Tobacco caterpillar (*Spodoptera litura*) and Bihar hairy caterpillar (*Spilarctia obliqua*) are the major damage causing insects of soybean. Integrated pest management strategies based

on surveillance have been recommended to farmers to control the pest attacks.

The shift in disease scenario in terms of emergence of new diseases and pests or a hitherto minor disease or insect pest assuming disastrous proportions owing to change in temperature, rainfall and CO_2 regime warrants a well planned and laid out surveillance, monitoring, forecast and control system to be in place. In addition, development of new control strategies and improvisations of older recommendations would also carry the torch for future research endeavors. Control measures of future would require them to be inclusive in nature which embroils not only the target pest and crop but also the agro-ecosystem, tillage practices and market requirements.

Managing climatic aberrations

Inter-government panel on climate change has projected that by the end of century, global temperature is likely to increase by 1.8-4 °C along with increased frequencies of extreme events such as prolonged dry spells, floodings etc. These projected changes in climate will have considerable impact on soybean production and productivity. The climatic aberrations are already evident in soybean growing regions as the monsoon patterns have become more erratic than earlier and altered dynamics of key insect pest and diseases. Therefore, to make soybean cultivation a sustainable venture, the focus will be on impact analysis and development of adaptation strategies for mitigating the adverse effects of climate change. The multi-disciplinary efforts at war footings would be the requisite to meet this goal.

Soybean : A functional food

Soybean as a crop in the country has grown by leaps and bounds, but this primarily could be attributed to readily available international market for soybean DOC. With growing competition from USA and South American countries, for sustainable future of crop in India, soybean economy has to develop strong roots in domestic market also. Hence, it is of

Vegetable type soybean

paradigm importance that soybean assumes its due important role in nutritional security of malnourished masses.

Soybean is considered to be a functional food as it contains significant levels of biologically active compounds that impart health benefits beyond basic nutrition. It is a cheapest source of high quality protein (40%) which is rich in essential amino acids such as arginine and lysine needed for growing children. Its seed contains about 20% oil with an ideal balance of omega 6 and 3 fatty acids. It also contains good amount of minerals particularly iron, calcium along with vitamins, fibers and phytochemicals like isoflavons and other health beneficial compounds. However, the food uses of soybean in the country are very meager (5-6%). Currently, almost 100% of oil extracted from soybean is consumed in the country, while about 70% of the de-oiled cake is exported for animal and poultry feed. The remaining 30% of the cake is utilized in the country mainly for animal and poultry feed. With growing population coupled with increased purchasing power and changing consumer preferences, soybean can play a vital role in keeping the nation healthy. Despite its rich nutritional profile and varied uses, exploitation of soybean in food has been limited because of its beany flavour (lipoxygenases) and presence of anti nutritional factors like trypsin inhibitor. Fortunately, these limitations could be overcome by introgressing null lipoxygenase and null KTI genes. Breeding for quality characters and development of food grade varieties would be an important objective in future Therefore, the focus will remain on developing technologies that can lead to increased utilization of soybean as a food in the country and to make it a driving force for promoting the secondary agriculture through vegetable soya, soy-based dairy analogs (soy-milk, tofu), full fat soy-flour, snack foods, sprouted bean, tempeh, miso, natto, sauce and soy candy.

Transfer of technologies

Real worth of any technology lies in its adoption by users. Soybean improvement, production and protection technologies are no exception to this. Therefore, DSR has strived hard to take its technologies to soybean farmers through a number of special use vehicle programmes. Despite concerted efforts to disseminate the improved production technologies, the average productivity of soybean in India has remained low. The simulation studies as well as on farm trials conducted across various agro-climatic zones have indicated an irrigated yield potential of 3.0-3.5 t ha^{-1}

and a rainfed yield potential of 1.8-2.5 t ha^{-1} against the national average productivity of 1.1 t ha^{-1}. Therefore, there is an urgent need to fill the gap between actual yield levels and the potential of the crop. Additionally, considering nutritional prospects of soybean, there is a need to popularize soybean for food uses. Increased food uses of crop would lead to its full exploitation through secondary agriculture also.

Effective dissemination of future technologies with ever changing clientele profile would require a paradigm shift in approaches adopted by extension agencies. Future training programmes need to be devised as "self-to-do" kits for deeper penetrance among target groups that would be younger in age, modern in their outlook and keener to adopt. Hence, our technologies and their dissemination modules would required to be revamped using modern tools of ICT so as to cater to new needs in more effective manner.

Genetically modified (GM) soybean

The first genetically modified soybeans were planted in the United States in 1996. More than one and half decade later, GM soybeans are planted in nine countries covering more than 70 million hectares constituting more than 75 % of the soybean area world-wide. Among all the GM crops, soybean stands first in acreage in the world. Among major soybean growers; Argentina (100 %), USA (93 %), Brazil (71 %) have considerable area under herbicide tolerant soybean that provides them with an edge over other growers in terms of higher productivity at lower costs. Hitherto, India has avoided GM soybean so as protect its international market such as countries of European Union, South East Asia including China. Of late, there is a growing acceptance of GM crops in these countries and the time is ripe when country can think of providing GM technology an opening in soybean. It becomes more so important not just for effective weed control but also in wake of increased predation of soybean by defoliators. Focus will be on developing genetically modified soybean to overcome the problems of weeds, defoliators, biotic & abiotic stresses and other industrial purposes.

Strategy and Framework

MAINTAINING the focus on providing the upward thrust to soybean production and productivity in next twenty years to come, the following multi-pronged strategies have been formulated meticulously.

- Improving productivity of soybean through development of new genetical technologies.
  - Enhancing and enriching the gene pool to broaden the selection pool along with gene flagging to assign the worth to soybean genetic wealth.
  - Development of new varieties that would fit into futuristic crop management regimes and can harness the opportunities created by shift in weather patterns.
  - Exploitation of heterotic vigour to create an opportunity window for development of hybrids for further increasing yield potential.
  - Exploitation of new biotechnological tools in exercising efficient selection in reduced time frame.
  - Development of varieties with efficient extraction metabolism to assimilate ever limiting phosphorous and zinc availability.
  - Breeding varieties that could cope with abiotic stresses like water deficit and excesses.
- Re-aligning the production technologies to mitigate adverse effects of climate change.
  - Development of production technologies that would be able to mitigate the adverse effects of change in climatic patterns.
  - Identification of efficient soil microbes with better nitrogen fixation abilities and also with the ability to solubilize soil phosphorous and zinc.
  - Farm machineries for efficient replacement of human and animal component to attain better land preparation, sowing, interculture and harvesting operations.
  - Matching production technologies to go with organic

farming so as to capture huge potential market for organic soybean.

- Technologies that are in tune with conservation agriculture for the prolonged sustainable use of resources.

- Development of crop protection modules for effective control of biotic stresses.
  - Protocols for efficient crop, pest and diseases surveillance, monitoring and forecasting in different soybean production zones.
  - Protection modules keeping in view the possible changed occurrence patterns of existing pests and diseases and battle readiness to tackle any new emerging pest.
  - Development of efficient protection measures for effective and economic control of biotic stresses.
  - Development of integrated pest management with added dimensions of new pest control measures.
  - Utilization of novel genetical approaches such as development of transgenics for better pest control.
- Development of specialty soybeans to widen its utilization platform.
  - Development of specialty soybeans such as vegetable type and other types for special uses so as to promote secondary agricultural activities to further strengthen soybean's domestic marketability.
  - Exploitation of new genetic tools for allele mining and tagging soybean germplasm for these valuable quality traits.
  - Breeding varieties with added advantages of possessing these characters to suit the specific industry needs.
- Effective technology dissemination modules to bridge the technology gaps.
  - Technology dissemination modules that provide as wholesome solutions to soybean producers for their needs.
  - Re-alignment of extension programmes to cater to the needs of clientele groups that would decisively be different from older generation in their outlook and adoption behavior.
  - Renewed extension thrust to bolster the soybean related secondary agricultural ventures among farmers.

Epilogue

DIRECTORATE of Soybean Research has the national mandate to develop and propagate technologies for farmers of different economic strata and industry alike to take soybean production and utilization to new heights. Changing market preferences, emerging new trends in farming with the vital issue of climate change has posed multitudinous challenges to soybean research fraternity. Research and technology adoption gaps have been there in past also and so far DSR has provided needed technology backup to boost the soybean area and production in the country. Among all oilseeds, soybean has recorded the highest growth rates for both area and production. This phenomenal growth has been made possible only by significant contribution of DSR and its AICRPS allies in terms of high yielding varieties, efficient production technologies and better plant protection measures. Effective dissemination of new technologies also resulted in faster adoption of technologies by farmers as is evident by higher seed replacement ratio in soybean in comparison to many other crops.

New challenges that soybean would possibly face in next two decades to come would be of altogether different nature and humungous proportions. Research technologies as have been elaborated upon in this document would require concerted efforts from all the stake holders. Genetical, production and protection technologies have to re-align themselves with new climatic trends and market realities and demands. There would be added dimensions to research-clientele interface. Vision 2030, would go a long way in helping researchers, policy makers, industry and other stake holders to tackle these issues in holistic and participatory manner.

Annexure I: Strategic Framework

Goal	Approach	Performance measure
Augmentation, enhanced utilization, worth assessment and protection of soybean genetic resources.	Broadening the available soybean genetic resources through gift, import and exchanges from potential sources.	Inflation in size of PGR holding at DSR that would be shared among NARS Centres.
	Genetic enhancement of germplasm through pre-breeding exercises for expanding the parental base of varietal evolution programmes.	Diversification of parents that would be evident from pedigree of entries contributed to AICRPS Varietal Trials.
	Allele mining for flagging the useful genes available in the genetic stock for ascertaining the genetic worth of the collection and better utilization.	Lines that are found to be possessing special traits would be sent to national registry for protecting the genetic wealth.
	Molecular characterization of available soybean genetic stock for safeguarding country's interests.	Molecular data base that would be available for ascertaining the identity of genetic stocks.
Genetic enhancement of soybean productivity for food security under changed climatic and agro-management scenario.	Breeding higher yielding soybean varieties/hybrids through diversified parentage and new approaches (exploiting hybrid vigour) for developing soybean suited to changed needs and are able to break yield plateau under existing situations.	Enhanced productivity levels of released varieties that would ultimately lead to increase in national average productivity.
	Utilization of molecular tools such as marker aided selection for tracing QTLs for yield and their subsequent exploitation through breeding programme.	Development of lines possessing all major QTLs for yield and other associated traits that would record superior yields.

Goal	Approach	Performance measure
Genetic ameliorations for mitigating biotic/abiotic stresses, changing climatic and agro-management conditions.	Developing varieties suitable to drought, water logging and temperature stress for mitigating yield losses.	Varieties having resistance / tolerance to abiotic stresses.
	Breeding soybean with in-built resistance to major diseases such as YMV, Rust and other emerging disease complex and insects such as defoliators and girdle beetle.	Reduction in out-breaks of these menaces and, hence, the yield losses.
	Use of photo-insensitivity and long juvenility traits for development of soybean varieties with wider adaptability.	High yielding, early maturing soybean varieties having wider adaptability.
	Sustained soybean production from conservative agriculture with minimum use of inputs.	Development of breeding stocks for sustained production under resource limited conditions.
	Studying the molecular processes involved in soybean under biotic and abiotic stresses employing global gene expression, transcriptome profiling and proteomic techniques.	Development of engineered soybean cultivars resistant to biotic and abiotic stresses.
	Studying the multitude of cellular processes in related genera through translational approaches with a view to widen the genetic base of the crop.	Imparting specialty traits to soybean by deploying molecular biology tools.

Goal	Approach	Performance measure
Improving soybean productivity through supply of quality seeds	Development of technology intensive soybean seed production and management practice to eradicate the bottleneck of loss of soybean seed quality.	Increased availability of quality seeds produced by the seed agencies and the farmers
	Promotion of seed village concept to improve supply chain management practices for farmers to make them self sufficient for best quality seeds.	Improved seed replacement rate among soybean farmers.

सोयाबीन उगाईये, खुशहाली पाईये।
सोयाबीन खाईये, स्वास्थ्य-सुरक्षा पाईये॥