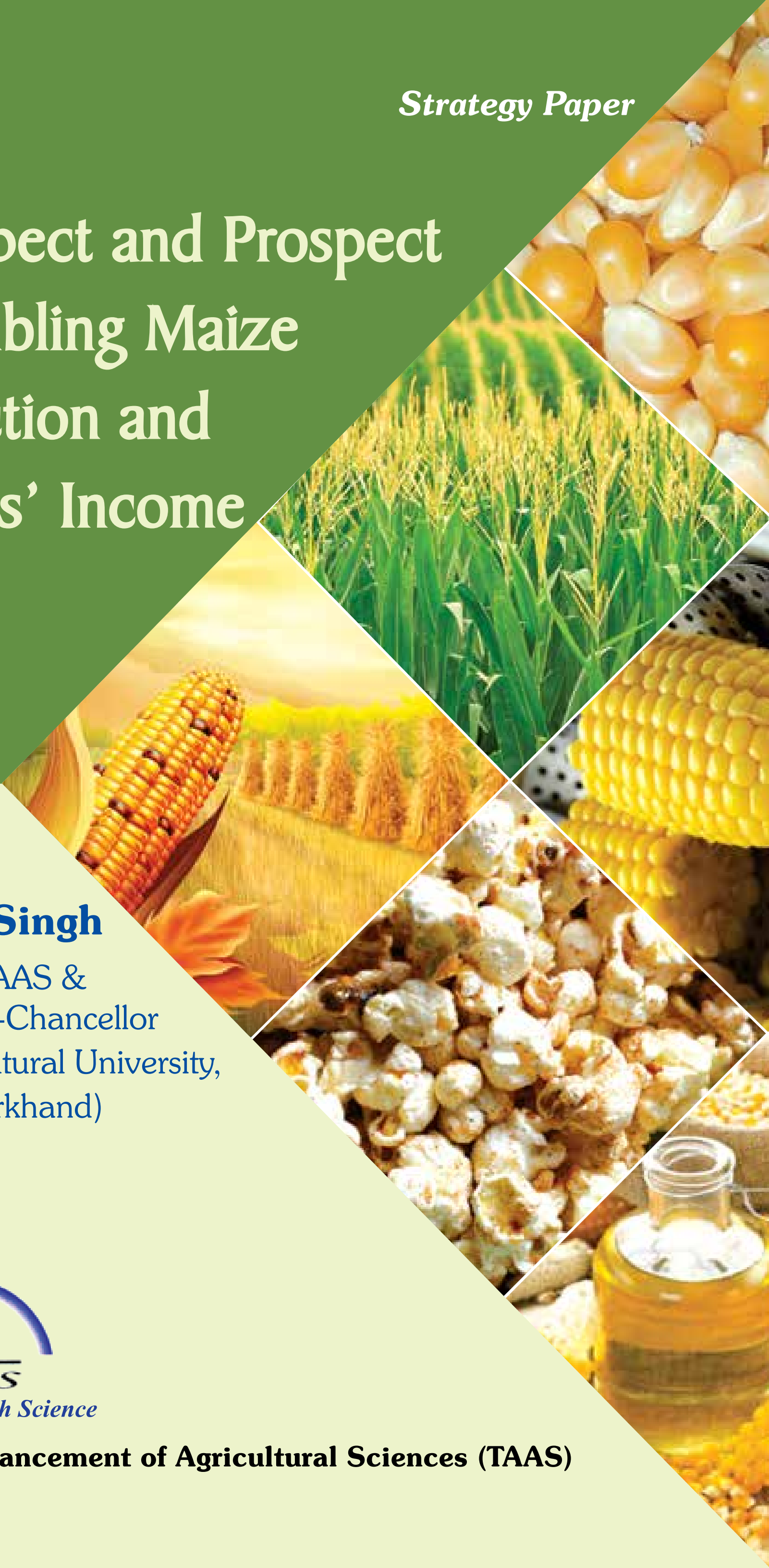
Strategy Paper

Retrospect and Prospect of Doubling Maize Production and Farmers' Income



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Progress Through Science

Trust for Advancement of Agricultural Sciences (TAAS)

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GOAL

An accelerated movement for harnessing agricultural science for the welfare of people.

MISSION

To promote growth and advancement of agriculture through scientific interactions and partnerships with stakeholders.

OBJECTIVES

- To act as think tank on key policy issues relating to agricultural research for development (AR4D).
- Organizing seminars and special lectures on emerging issues and new developments in agriculture.
- To institute national awards for the outstanding contributions to Indian agriculture by the scientists of Indian and other origin abroad.
- Facilitating partnerships with non-resident agricultural scientists visiting India for short period.

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Foreword

Maize (*Zea mays* L) is one of the most versatile crops after rice and wheat having wider adaptability under varied agro-climatic conditions. Globally, maize is known as queen of cereals because it has the highest genetic yield potential. It is cultivated on nearly 150 m ha in about 160 countries, representing diverse soil, climate, biodiversity and management practices, and contributes 36 per cent (782 m t) in the global grain production. Adaptability of maize across diverse environments, and its multifaceted use as food, nutrition, feed, fodder, fuel, Industrial raw material and for environmental security is well known. In India, enormous progress has been made during the last six decades to enhance yield potential through genetic improvement and alleviate effects due to various biotic and abiotic-stresses.

On the recommendation of Dr. E.J. Wellhausen Committee, first All Indian Coordinated Research Project on Maize was initiated by ICAR with support of Rockefeller Foundation. It had the concept of multilocation and multidisciplinary approach. In the last 60 years, maize area, production and productivity has increased manifold. Maize revolution with highest growth rate among all crops is seen across the nation due to adoption of new technologies, including modernization of maize production.

This Strategy Paper ***"Retrospect and Prospect of Doubling Maize Production and Farmer's Income"*** presents an overview of the journey of maize research in India. It covers major initiatives taken by the Government, projection for future maize demand, genetic improvement and expected impact on productivity and production, crop productivity challenges, value addition, role of youth and women. Various strategies viz., composite breeding, double cross, three way cross and single-cross hybrid breeding have been adopted in cultivar development to enhance productivity across a range of production ecologies. Development of cultivars having tolerance to abiotic-stresses (water and temperature extremes) and resistance to diseases has been a priority area in maize improvement. Both conventional and molecular approaches have been used in the development of disease resistant, stress adapted and nutritionally superior cultivars. Enabling policy initiatives to remove bottlenecks coming in the way have also been addressed to encourage Public-Private-Producers-Partnerships to enhance productivity. An attempt has also been made to highlight past achievements made and suggested a possible Way Forward.

Efforts of Dr. N.N. Singh, former Maize Project Coordinator/ Director in compiling and attempting this Strategy Paper is indeed praiseworthy.

September 10, 2017

(R.S. Paroda)
Chairman, TAAS

Retrospect and Prospect of Doubling Maize Production and Farmer's Income

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After Independence in the year 1947, the Union Government realized the importance of agriculture, and in 1953, the Indian Council of Agricultural Research (ICAR) constituted a high powered committee with Dr E.J. Wellhausen as Chairman and Dr U.J. Grant as member. Considering the fact of maize-crop with the highest productivity among all the cereals along with wider adaptability to diverse environments, the committee in 1954 recommended establishment of an All India Coordinated Maize Improvement Programme. Also, maize crop in India was considered very suitable to the needs of small and marginal farmers due to its varied utilities as food, feed, fodder, fuel, specialty corn, diverse industrial uses, and flexibilities to fit in crop diversification, cropping system/ farming systems.

The ICAR implemented the recommendations of the committee and with the generous support of the Rockefeller Foundation (RF) established the first All India Coordinated Maize Improvement Project (AICMIP) in 1957. Initially, the AICMIP was limited to disciplines of Breeding and Agronomy with 17 centres in major maize growing states of the country. In 1963, disciplines of Entomology and Pathology were added with the support of PL480. The objective of the AICMIP was to develop and release widely adapted high yielding cultivars, resistant to major diseases and insect pests, and to avoid duplication of breeding efforts through extensive multidisciplinary and multi-locational testing. A Winter Nursery was established at Hyderabad in 1962 for off-season advancement of generation of breeding materials. The location was selected for its congenial environment to grow two maize crops across the year. Hotspots for major diseases and insect pests were identified and sick plots were developed to screen materials at different locations. During those days selection of centres was not easy due to lack of proper connectivity through rail, road and air. And most of the state government farms were located in remote places without electricity, facilities for irrigation water and necessary infrastructure to develop laboratories. Since there was only one agriculture university at Pantnagar (in 1960-61), the need to establish universities in the other states were realized. The selected farms for maize research later became university research farm and centre. The entire country was divided into five agroclimatic zones, and in each zone, one main centre was identified– Zone I - Srinagar; Zone II - Delhi; Zone III - Pantnagar; Zone IV - Hyderabad; and Zone V - Dholi. The main centres were further strengthened with all major disciplines to develop and generate material and the rest of the centres in the zone were utilized for testing breeding material. Subsequently, all centres were involved in development and testing of breeding material. The coordinated project was elevated as Directorate in 1994 and at present in 2015, it has been further raised to the status of an institute with more than 30 centres, including cooperating centres with mandate of basic, strategic and applied research for overall improvement of maize in the country.

Maize, a predominantly rainy season (*kharif*) crop, was grown up to 1980s mainly in Uttar Pradesh, Bihar, Rajasthan and Madhya Pradesh. However, lately it is grown more predominantly in peninsular India– undivided Andhra Pradesh (20%), Karnataka (17%), Maharashtra (11%), Bihar (9%), Tamil Nadu (8%), Madhya Pradesh (6%), Rajasthan (6%) and Uttar Pradesh (5%). The crop is grown in all seasons, i.e., winter (*rabi*), rainy season (*kharif*) and summer (spring season) in all parts of country, except Goa and Kerala and also in all environments (tropical, sub-tropical, temperate, highlands) and thus, it offers flexibility in crop diversification. Maize has the highest Compound Annual Growth Rate (CAGR) of 4.98 per cent in yield compared to all other cereals. Globally, maize was grown in 2014 in 165 countries, over an area of 184 MHA with total annual production of 1,065 MMT and productivity of 5.52 tones/ha (FAOSTAT, 2014). Due to its high demand, mainly as animal, poultry and piggery feed, maize has emerged as the most cultivated crop in the world. In India, it is mainly used as feed (59%), industrial raw material (17%), food (10%) and about 10 per cent for other purposes like export, seed etc.

Up to 1950-51, maize production scenario in India was very dismal ; production was only 1.73 MMT. This was due to its low productivity and less area under its cultivation. Prior to the inception of the AICMIP, maize research and development was limited to collection and selection from local germplasm within the states. During the days there was no systematic approach to introduce exotic germplasm for use in the breeding programme. Hybrid technology was also not used due to lack of exotic germplasm in spite of maize revolution during 1930s in Europe and North America. By 1958-59, maize production doubled (3.46 MMT) primarily due to increased area (35%) and productivity (48%) and was achieved due to low base for yield and selection done in local germplasm by Systematic Botanists of the states.

After the establishment of AICMIP in the year 1957, major emphasis was given towards introduction of exotic germplasm, mainly from North and South America and Caribbean region with the support of Rockefeller Foundation. Then introduction was easier as the germplasm was considered common heritage of mankind. Further, a systematic programme on collection and characterization of indigenous germplasm was taken up for traits of economic importance by maize scientists. Owing to lack of storage facilities in the Plant Introduction Division of the Indian Agricultural Research Institute (IARI), storage of large germplasm collections became difficult. Hence, similar collections were bulked, which were called Indian Maize Collection bulks (IMC bulks), and a total of 110 IMC bulks were maintained under the project. During this period,

Corn Belt inbreds were extensively introduced. Using these lines, the first set of four double cross (DC) hybrids- Ganga 1, Ganga 101, Ranjit and Deccan, were developed and released for commercial cultivation in 1961. Initially, two progressive farmer organizations,. Massina Beej at Samastipur, Bihar and Tonnage Club at Dahod, Gujarat, started producing seeds of maize hybrids. Since, the farmers were not aware of the yield advantage of hybrids, marketing of hybrid seeds was a problem. Its important to mention the efforts made by the above two producers in popularizing hybrid maize in their areas. However, the meager amount of seeds produced by Massina Beej were loaded on cart and distributed door- to- door to maize farmers with an assurance to pay cost of seed after harvest if they had yield advantage over local cultivars. This strategy worked well and farmers became aware of advantage of hybrid seeds. The contribution of Massina Beej cannot be forgotten in spreading high yielding cultivars of maize in Bihar.

Major Initiatives between 1960 and 1970

The release of double- cross maize hybrids demanded establishment of infrastructural facilities to produce hybrid seeds. Since, there were no facilities for seed production, National Seeds Corporation (NSC) was established in 1963 for production of hybrid seeds. Seed production and certification in the beginning was carried out by the NSC. However, sooner certification was delinked by the Ministry of Agriculture, Government of India, with the statutory provision to assure seed quality to farmers. Provision to sell truthfully labeled (TL) seeds was allowed to the private sector seed producers by the Government, so large amount of seeds could be produced and sold to farmers at their own risk to assure quality. In 1962, the RF provided three small seed- processing plants, one each at the IARI, New Delhi; Massina at Samastipur, Bihar; and Dahod, Gujarat. Terai Development Corporation (TDC) was established in 1965 at Pantnagar and later 13 more State Seed Corporations came into existence. This period was crucial as the country was facing acute shortage of foodgrains. However, with the development and popularization of high yielding varieties of wheat and rice by 1965-66, the priority shifted to seed production of these crops by the National and State Seed corporations, and the country witnessed Green Revolution. The constraints of producing hybrid seed bred by public sector was realized by private sector and private seed companies in the country initiated production of hybrid seed.

Rockefeller Foundation also established Inter Asian Corn Improvement Programme (IACP) with Headquarters at Bangkok, at farm Suwon, and started developing pools and populations with an objective to develop collaborations among Asian Countries for upgrading and exchange of material. In the year 1966, International Maize and Wheat Improvement Center, (CIMMYT) at Mexico came into existence, and a large number of exotic germplasm were introduced in the form of pools and populations.

Indian maize scientists soon realized that the demand for seeds in the country cannot be met by meager production of hybrid seeds and a conscious decision was taken to focus and raise level of base germplasm with twin objectives- (i) to release composite varieties as cultivars for commercial cultivation so that farmer could use seeds from his own produce up to 3-4 years without much loss in productivity and (ii) to raise population base to extract more productive inbreds for developing hybrids. This helped raise level of pools (as a back-up activity) and to develop full-sibs to refine pools as the populations (advance units) and also select ten top yielding progenies to develop experimental varieties for release. The CIMMYT started characterizing germplasm available in its gene bank; collected mainly from Central and South Americas and Caribbean regions. The pools were refined further and populations were developed. The full-sibs developed by the CIMMYT for each population were sent to the Indian National Programmes. The maize project scientists as partners in active collaboration with the CIMMYT started pre-breeding activity by screening germplasm for yield, resistance to diseases and insects- pests through the international progeny testing trials (IPTT), experimental variety trial (EVT) and elite variety trials (ELVT); by growing in different agro-ecologies. Planting of trap nurseries at all locations of the project with 2-3 susceptible and 2-3 resistant germplasm of major maize diseases and insect- pests became regular feature to find out natural occurrence of specific diseases and insect- pests in a particular region and season. This helped establish sick plots at hot spots for mass screening of germplasm. Later, the trap nurseries were converted into survey and surveillance nurseries (SSN) to watch occurrence of new diseases/ insect- pests and their races.

India became the first country in the world to release 6 composite varieties, Vijay, Kisan, Amber, Vikram, Sona and Jawahar, in 1966 for commercial cultivation by crossing exotic pools and populations with the native germplasm. It was also decided to develop double top cross (DTC) hybrids by crossing a single cross with a variety for commercial cultivation for faster production of seeds in addition to DC hybrids. DTC hybrids., Ganga Safed 2, Ganga 5 etc., were released as cultivars. Two mutants with high lysine and tryptophan, Opaque-2 (O_2) and high methionine flory-2 (fl_2) were introduced during 1965-66, and in 1971, three quality protein maize (QPM) varieties, Shakti, Rattan and Protina with soft endosperm type, were released for the first time in the world for commercial cultivation. These varieties could not become popular in spite of quality traits owing to loose packing of starch in the endosperm, dull texture, vulnerability to diseases and pests of stored grains. A hard endosperm QPM variety, Shakti 1 was developed taking advantage of the modifier. However, this variety owing to lower productivity compared to normal maize did not become popular. Composite varieties and DTC hybrids, however, became popular among farmers, and maize productivity improved significantly leading to doubling, reaching 7.49 MMT. This was achieved mainly due to increased yield (58%) and partly to increased area (37%).

Major Initiatives between 1971 and 2000

During this, the ICAR allowed private sector seed companies to produce and sell seeds of public- bred hybrids in original name and started providing their parents and those of composite varieties, which was restricted earlier only to public sector corporations. Some seed companies also started their own R&D to develop hybrids and produce certified and TL seed. This helped meet requirements of quality seed The ICAR was involved in testing all hybrids/varieties, developed by both private and public sectors in the coordinated trials, so to identify, release and notify the best hybrids suitable for different ecologies. Till 1980, public bred hybrids produced by Public and Private Sector agencies dominated. An initiative was taken by the FAO-RAP, Bangkok, to establish a Tropical Asian Maize Network (TAMNET) to test and exchange hybrids developed in the Asian Countries with an objective to find out hybrids and germplasm suitable in other Asian Countries and to share information through a newsletter- 'TAMNET Newsletter'.

The ICAR strengthened and supported maize hybrid development programme also by doubling contingency in 1975 to develop hybrids suitable for winter and spring. The maize project started developing open ended heterotic pools in different maturity groups by ascertaining heterotic patterns of inbreds, pools, populations, varieties etc. using parents of the best single- cross hybrid as testers. Objective of this was to extract inbred parents from these pools, which would be heterotic to each other. Simultaneously introgression of temperate germplasm into tropical materials was also carried out. The level of introgression was monitored so that germplasm could adapt to varied agro-ecological conditions of the country; severe to mild cold. Some centres focused on extraction of inbreds through inbreeding in the best single crosses, which was largely a short term strategy. The project introduced large number of inbreds, developed by the CIMMYT and used directly to develop hybrids after acclimatization. Screening of inbreds developed or received from CIMMYT was done for biotic and abiotic stresses under artificial inoculation infestation and in high plant population densities, to identify resistant lines withstanding high plant population densities in hybrid combinations.

The hybrid development programme was further strengthened under the New Seed Policy in 1988-89 with emphasis to develop single -cross hybrids. The first single cross hybrid, 'Paras', was released by Ludhiana Centre in 2001-02. Private sector was reluctant to develop and produce single crosses owing to fear of theft of parental lines of hybrids. Single cross hybrids developed by the project having better productivity than DC or DTC hybrids attracted attention of the private sector seed agencies to produce seed on royalty basis with non-exclusive right. It was realized that private sector and multinational companies would not invest to develop best hybrid products (single crosses) unless protection of their parents is assured. This was the major impediment to enhance productivity and increase production of maize. Realizing this, ICAR with the Seed Division of Ministry of Agriculture drafted two key bills- Protection of Plant Varieties and Farmers' Rights Act (PPV&FRA), 2001 and National Bioversity Act, 2002 ; enacted by the Indian Parliament. This was the turning point in doubling production and productivity of the crop. During the period, production was recorded up to 60 per cent increase, while area increased by 25 per cent. The CIMMYT also strengthened and established a biotech programme through a network, 'Asian Maize Biotech Network (AMBIONET)' at the Division of Genetics, IARI, New Delhi in 1998, thus India was a partner.

Major Initiatives between 2001 and 2015

The protection provided in the PPV&FR Act encouraged private sector to invest more to develop single crosses or modified single crosses and produce seeds of single- cross hybrids. At present, about 22-25 per cent area is grown with single- cross hybrids. Area under winter and spring maize also registered a steep growth of 270 per cent. Average productivity of winter maize was as high as 5.0 tones/ha and some farmers harvested up to 11-12 tones/ha due to the favorable ecology, i.e., irrigated condition. Also, due to high profit, about 30 per cent irrigated area was shifted to *kharif* maize.

Maize scientists were quick to develop and release more than a dozen QPM maize single cross hybrids using hard- endosperm type inbreds received from the CIMMYT. Scientists at Almora Centre used molecular marker assisted selection (MAS) method to shorten breeding period. Molecular markers in QPM hybrids were already known to exist within the opaque-2 gene, and these markers were capable of detecting opaque-2 gene even in heterozygous state. Utilizing this novel technique that accelerated conversion of normal maize inbreds into QPM inbreds, the first QPM maize hybrid QPM Vivek 9 was released using MAS method. Increased demand of maize for feed and industrial uses contributed significantly to increased maize area, resulting in compound annual growth rate of 4.98 per cent. In the last 16 years, more than 10 MMT were added, reaching to a total maize production of 26 MMT.

Future Maize Demand

Demand for feed

Currently with a total production of 26 MMT, the country is able to meet domestic demand of maize. Out of this total, about 15 MMT

(60%) is being utilized as feed, of which 12.5 MMT (84%) is used as poultry- feed alone and rest as animal- and piggery- feed. With 8-10% growth in poultry sector and 1.3% in livestock sector, the total maize requirement as feed is likely to go up to 32-33 MMT by 2022.

Poultry feed

Due to fast growing Indian poultry sector from 2000 to 2016, broiler meat production increased from 0.8 MT to 4 MT and egg production from 37 billion eggs to 70 billion eggs. Maize is ideal feed for poultry and is used extensively as the main source of for calories and crude fibre content. However, due to major cost (about 60-70% incurred on the feed component alone), poultry sector is facing challenges, which can be reduced to half using reduced quantity of QPM maize- offering best sources of poultry, livestock, piggery and fish feed as well energy with doubled biological value. The annual demand of maize is expected to increase due to consumption of poultry meat and eggs at 9 and 5 per cent, respectively, over the next few years.

Animal feed and fodder

Dairy farming is fast emerging as a potential business in rural and peri urban India; the country has one of the largest livestock population (>500 million), likely to grow at the rate 1.3 per cent in near future. It is estimated that by 2022 a total of 526 MT of dry matter, 855 MT of green fodder and 56 MT of concentrate feed, comprising 27.4 MT of cereals including maize as main component, 4.0 MT of pulses, 20.6 MT of oilseeds, oilcakes and meals and 3.6 MT of manufactured feed would be required. The quality of maize fodder is considered better than sorghum and pearl millet, as the latter crops possess anti quality components such as HCN and oxalate, respectively. Therefore, there is a tremendous pressure of livestock on the available feed and fodder as land available for fodder production is decreasing. Maize crop residues such as dry stock and shanks as feed, besides maize- plants as fodder and specially corn i.e., sweet corn, baby corn, corn for green ears after harvest of green cob as fodder and silage for lean season can be complimenting fodder needs.

Demand for food

The demand for maize as direct human food is likely to increase from 1.3 to 3-4 MMT. This would come more from availability of specialty corn products like sweet corn, baby corn, popcorn, corn for green ears and QPM products besides traditional use of maize flour, multigrain flour and other dry milling and alkali processing products. The rising interest in the above products is more in urban areas. Consumption in rural areas can be increased if maize is provided through public distribution system (PDS) in Bihar, Odisha, Rajasthan, Jharkhand, Himachal Pradesh, Jammu and Kashmir, Gujarat etc. where maize forms part of staple food along with other cereals.

QPM offer very good opportunity and cheapest source of quality protein to address food and nutritional security. Normal maize protein is known to have a biological value of 40 per cent only of that of milk, and therefore it needs supplementation from legumes and animal products. Essential amino acids, like lysine, tryptophan and threonine are in reduced quantities; lysine being most limited, followed by tryphophan. QPM has nearly twice the amount of lysine and tryptophan, which equates QPM to 90 per cent of milk protein. QPM can benefit the worst victims of malnutrition, infants, pre-school children, adolescents, lactating women, pregnant women and old aged persons as a superior food. Due to availability of high yielding single- cross hard endosperm QPM maize hybrids without yield penalty (now at par in yield with normal maize with double biological value higher than wheat and rice matching with skim milk for true protein digestibility), the need is to exploit potential of QPM as a health food for the vulnerable segment of the society. QPM is considered as a miracle maize because all cereals except QPM are deficit in lysine, an essential amino acid, and all pulses deficient in mithionine, another essential amino acid. Due to the above qualities, the demand of maize as a food is expected to more than double by 2022.

Sweet corn and baby corn possess high quality phyto nutrition profile comprising dietary fibres, vitamins and antioxidants in addition to minerals in the moderate proportion. Besides proteins, vitamins and iron, sweet corn and baby corn are one of the richest source of phosphorus. Baby corn is high in folate, B6 vitamins, riboflavin and vitamin C. It contains two carotenoids, zeaxanthin and lutein, which help prevent cataract. In sweet corn, sugar content is around 15-20 per cent compared to 3-5 per cent of the field corn. The demand for sweet corn and baby corn is rapidly increasing in urban areas of the country. It has potential for export in domestic and international markets. The crop can be grown round the year and 3-4 crops can be taken up within a year. India has emerged as one of the potential baby corn and sweet corn producing country and its cost of production is also low.

Industrial demand

Corn starch is generally processed by wet- milling method as the primary product and the other products are corn oil, corn steep, liquor, glutin etc. The average recovery of various products during wet milling is as follows: starch (60-62%), glutin (8-9%), germ (6-7%) and husk (22-24%). The glutin and germ are mainly used for poultry feed and corn oil, respectively. By products of dry and wet milling industries are being used as raw material for preparation of formulated feed sweetener products (such as corn syrups used in bakery) and dry products. Non-food uses of corn syrups are as bodying agents in inks, shoe-polish, textile finishes, adhesive formulations, pharmaceuticals in tanning leather and as humectants in tobacco. Dextrose is a major component of table-candies, chewing- gums, gum- confections, fondants and hard-candy formulations. Sorbitol is used in the production of synthetic vitamin C, high fructose corn syrups, and in a variety of ways such as confections, baked goods, table syrups, sweet beverages etc. Corn oil a highly desired vegetable oil is commercially produced from corn- germ(isolated by wet milling or dry milling); used due to its high content of unsaturated fatty acids for reducing blood cholesterol levels.

Maize is also extensively utilized in fermentation industry as beverages to produce beer and distilled liquors, wines (sweet “pop wines” and “wine coolers”), antibiotics, enzymes, fuel -alcohol and chemicals . Maize -cob granules are used as carrier for pesticides, fertilizers, vitamins, extraction of crude petroleum, hand soaps, cosmetics etc. The per capita consumption of starch and industrial products in the country is expected to increase from the present level of 4.25 MMT to 15 MMT by 2022, and maize being the major source of industrial starch, its demand would increase proportionately.

Maize for export

Maize was in short supply owing to fast growing poultry industry, and up to 1980s its domestic demand could not be met. Lately, the situation has reversed, and India is exporting maize to South East Asian Countries, such as Indonesia, Vietnam, Malaysia etc. due to cheaper transportation and better competitive prices. The Middle East countries also offer very good market for maize.

Maize Productivity Challenges

Though productivity of *rabi*/spring maize is more than doubled of *kharif* maize; *kharif* maize covers over 83 per cent maize area. To enhance maize production, productivity of *kharif* maize needs to be increased. About 75 per cent *kharif* area is rainfed , while *rabi* maize is predominantly grown in favourable ecologies. With increase in irrigation facility, some areas of *kharif* maize are also cultivated with irrigation due to its comparative advantage in productivity than other *kharif* crops. Although the crop can be grown in all environments due to its wider adaptability but due to tropical and sub tropical environmental conditions such as shorter day length, early maturity, high night temperature, poor quality sunshine, cloudy weather etc. prevailing during *kharif* season, its potential productivity is not realized. Also, extreme weather events due to climate change exacerbate uneven rainfall, drought, flooding, temperature, high wind etc., which affect adversely maize productivity. Heat stress at flowering and grain filling in spring maize causes substantial yield losses. Biotic stresses such as post flowering stalk rot (PFSR), leaf blights, banded leaf and sheath blight (BLSB), downy mildews (DM), ear rots (ER), borers, and weed problems also adversely affect maize productivity. Non-availability of quality seed of single- cross hybrids is another important factor contributing to low productivity of rainfed *kharif* maize. The private sector is mostly focusing on development and production of single-cross hybrids suitable for low risk-high potential irrigated ecologies. Emphasis is given to develop improved cultivars tolerant to biotic and abiotic stresses with resilience to climate changes. In some parts of the country especially in the north-west plain region where rice-wheat cropping system is dominant, yield suffers owing to decline in total factor productivity. These ecologies require crop diversification through the introduction of maize. Adoption of good agronomical practices like integrated nutrient management, integrated farming system approach to improved nutrient use efficiency, conservation practices, water management and integrated pest management along with availability of single -cross hybrid seed are viable options in rainfed areas to stabilize yield of both low potential and high risk environment as well as high potential and low risk environment. Maize is very much vulnerable to post- harvest problems, which accounts for more than 20% losses. These losses intensify due to poor drying and storage leading to weevil damage and formation of mycotoxins. Innovative extension mechanism is required to outscale technologies for farmers to counter low adoption of improved technologies to bridge productivity gaps.

In the next 5-6 years maize area may increase from 9.2 Mha. To a maximum of 11-12 Mha, especially in the peninsular India, owing to favourable ecology for maize production in the region. The major increase in the *kharif* area of about 1.8 Mha and of 1.2 Mha in *rabi* may come from Karnataka, Andhra Pradesh, Odisha, Maharashtra and Tamil Nadu. To meet increased demand of maize, the major focus should be to increase productivity rather than area with an annual growth rate of 7-8 per cent. The target to achieve average productivity level of 5-6 tones/ha is possible by enhancing area under irrigation, crop diversification and improved agronomical practices during *kharif.*

Doubling Maize Production and Farmer's Income by 2022

Mission - mode approach is required to meet domestic demand of maize by 2022 and to make maize farming profitable, efficient, economically viable, knowledge based, environmentally sustainable and viable enough to attract local youth to ensure rural livelihood security. This would require 7-8 per cent CAGR in yield without much increase in area. This is attainable with 80 per cent area coverage with most productive single cross hybrids (resilient to climate change) by increasing productivity from the current level of 2.56 tones/ha to 5.0 tones/ha. Demand scenario especially for feed and industrial use is quite encouraging to attract farmers to cultivate maize because of assured market and strong techno–economic competitiveness. The gap between realized and potential yield clearly indicates availability of suitable technologies, however, the need is to effectively demonstrate innovations in farmers fields to bridge yield gaps, especially of *kharif* maize.

Initiatives taken by the Central Government for doubling farmer's income by 2022 and policy initiatives to conserve natural resources (soil, water), improve resilience and reduce risks, such as *Pradhan Mantri Krishi Sinchayee Yojna*, (PMKSY), *Har khet ko pani*, *Pradhan Mantri Fasal Bima Yojna* (PMFBY), National Food Security Mission (NFSM), National Horticulture Mission (NHM), National Mission on Sustainable Agriculture (NMSA), connect farmers' with remunerative markets through e-NAM (one Nation-one Market) and consolidate farmers to derive benefits through farmer's producer organization, moving towards more cash transfer and less public sector distribution of inputs and outputs are praise- worthy. Efforts need to be made to sensitize maize farmers' to take advantage of efficient use of resource-saving improved technologies, good management practices, small farm mechanization, etc. and to create enabling environment to promote available technologies reach to farmers of both rainfed and irrigated ecologies in cropping or farming- system mode including diversification to higher value crop or animal and beyond farm through value- added chains.

Strategies for Enhancing Maize Productivity

The research agenda need to be decided considering problems faced by farmers to address productivity issues emerging from their fields for both upscaling and outscaling innovations. In addition, action plan needs to be developed involving all stakeholder–planners, researchers, farmers, processors and traders in Public-Private-Producer-Partnership (PPPP) mode to address issues in a holistic manner, ensuring management of natural resources. The agenda for technology development in PPPP mode can play a very important role and reach to unreached through technology agents ,who would disseminate innovations and supply quality inputs such as seed etc. An evolved mechanism is desired which upgrade the knowledge continuously of all stakeholders right from researchers, technology agents, farmers etc. and the progress would be evaluated to access progress in a time- bound manner.

For Enhancing Breeding Efficiency

Strengthening pre-breeding activity

Considering productivity challenges, the aim is to have genetically diverse portfolio of improved maize cultivars (SC hybrid) suited to a wide range of agro-ecosystems and farming practices, resilient to climate change; as the genetic diversity would improve adaptability, and greater resistance to biotic and abiotic stresses to improve cropping system resilience. The research agenda should be focused on the development of new hybrids which are responsive to external inputs, use nutrient and water efficiently, greater resistance to biotic and abiotic stresses, adapted to unfavorable areas and production system, produce economic yields with higher nutritional value and are with desirable organoleptic properties. To attain the above, ensurance is required that the available diversity in gene banks and also in farmers' field is characterized. Donor alleles or traits of economic importance such as resistant sources to reduce genetic vulnerability resilient to climate change and nutritionally enriched traits for germplasm diversification are made available for pre-breeding activity to mobilize them efficiently and effectively in a timely manner with emphasis on per day per unit productivity increase. This can be achieved in collaboration with institutions involved in breeding and with farmers' participation for sustainable maize production intensification (SMPI). It would be appropriate to have bottom- up approach, considering farmers' needs in a particular agro-ecosystem to focus on resources important to enhance productivity, improve quality and adaptation to climate change for sustainable intensification with required financial support for pre-breeding.

In this context, it is of utmost importance to constitute heterotic pools on the pattern of stiff stalk synthetic and lancaster in the USA. Such heterotic pools are to be developed in three maturity groups. Long, medium and short by infusing newer germplasm from diverse sources in maize breeding programmes. A systematic programme to screen available germplasm such as pools, populations, varieties, inbred lines etc., both exotic and indigenous, are to be thoroughly screened for traits of economic importance and be constituted into heterotic groups using parents of best single cross as testers for each maturity groups. This was a continuous activity of the project in the past and constituted heterotic pools were kept as open ended with an idea to introgress new germplasm into their respective groups to broaden germplasm base to provide novel traits for enhancing breeding efficiency for the development of superior single crosses. The information on germplasm for each pool needs to be made available in pedigree book, to be brought out in every 2-3 years, to ensure that material introgressed once is not re-infused in pools, and a balance of introgressed material is maintained in each heterotic pool. In this context, six heterotic pools in three maturity groups developed by project and two heterotic pools in full season maturity group developed at the Ludhiana Centre, known as Ludhiana Stiff Stalk and Ludhiana Lancaster are worth -mentioning. The above pools are treasure of the project to extract inbred lines to develop new single- cross hybrids with very high magnitude of heterosis.

Genetic enhancement for stress tolerance maize germplasm

In the past decade, drastic climate changes have taken place and are likely to take place in future as well. The crop suffers owing to severe and erratic abiotic stresses culminating into heavy yield losses. This requires development of climate resilient maize germplasm with incorporation of traits which can tolerate drought, high temperature, water stress etc. There is need to execute breeding programme to make simultaneous selections under combination of stresses to develop cultivars. Efforts are to be made to recollect maize germplasm adapted under severe stress in farmers' fields and they are to be screened thoroughly under controlled stress to be used in the breeding programme. For this, managed screening sites and standardized protocols to screen germplasm for combinations of stresses under controlled conditions suited for a target environment are to be developed. Also, genetic engineering, RNA interference and targeted mutagenesis techniques are new tools to engineer maize germplasm resistant to biotic and abiotic stresses in a long run. There is a need to develop breeder ready markers for resistance to major diseases of maize.

Frontier technologies for enhancing genetic gains

So far, conventional breeding has helped to develop high- yielding maize hybrids. However, advances made in breeding techniques which have ability to develop cost- effective and time -saving maize cultivars with high yield potential, adaptive to biotic and abiotic stresses resilience to climate change, offer good opportunity. Double haploidy (DH), molecular marker-assisted (MAS) breeding, high throughtput precision phenotyping of traits of interest, year round nurseries and decision support systems/tools offer new ways for enhancing genetic gains and breeding efficiency. The time has come to strengthen public breeding programme to integrate with DH tools/techniques to improve breeding efficiency besides reducing costs and simplifying logistics. Maize breeding cycle has been reduced significantly with the available new genomic selection technologies. This has become feasible due to drastic reduction in genotyping costs. Genome Wide Association Studies (GWAS) implemented with high throughput precision phenotyping have emerged a powerful strategy for dissecting complex traits and identifying superior alleles contributing to improved phenotype in maize.

Breeding assisted with MAS is very effective. It helps in development of cultivars with combination of relevant adaptive and quality traits and tolerance to stresses. There is need to develop facilities to undertake precision phenotyping, particularly under repeatable and representative levels for stress in the field. At present, low cost easy to handle tools are available for field phenotyping of appropriately selected traits, and they should be the integral part in maize breeding programme. There is need to establish phenotyping network for comprehensive and efficient characterization of genetic resources and breeding materials for an array of target traits, particularly those linked to tolerance to biotic, abiotic and nutritional quality. This would greatly help in genomics assisted breeding diversification of genetic base of elite breeding materials and creation of novel varieties resilience to climate change.

Adoption and development of genetically modified (GM) maize

Research programme should be strengthened to develop GM maize with enhanced productivity and profitability to farmers by controlling insect- pests and weeds in the fields. However, utmost care should be given to ensure biosafety issues before promoting events as cultivar. This would go a long way to improve environment safety and health problems, caused by residue of chemicals used by farmers.

Production Technologies for Enhanced Productivity

Agronomy being a location- specific activity, all centres of the project are involved in development of location- specific agronomic practices to enhance maize productivity. Special emphasis is to be given to workout non-monetary output practices such as date of sowing, plant population density, method of sowing and fertilizer application.. Package of practices developed for each agro-ecology of the country, which pay very rich dividend is to be propagated among maize- farmers. A mix of inorganic and natural resources (manure, nitrogen fixing crops) should be included in the package of practices for better yields.

In the context of the present day problems like decline in total factor productivity making soil hungry and thirsty due to decrease in soil biota (beneficial microbes, arthropods, annelids etc.) and decreased organic carbon in the soil are hampering nutrient utilization efficiency in the field. Degrading soil and other natural resources (polluted water and air) also have adversely affected total productivity. Thus, there is a need to develop production technologies with bottom- up approach, considering farmers' fields conditions. The main challenge is to produce more from less land and water. Depletion of groundwater and deterioration of water quality thus calls for crop diversification and use of appropriate water saving technologies for irrigated maize.

There is need to critically analyze rainfall pattern and moisture problem in rainfed maize to establish production constraints and to take up an integrated location specific judicial approach. Deep rooted genotypes, improving water infiltration and water storage capacity at root zone and practices to minimize evaporation and lengthening of the duration of soil moisture from organic mulching and control weed in the field are some of the strategies to be followed to augment moisture. The agronomic recommendations made earlier with top- down approach are no longer valid due to extreme weather events and climate changes. There is a need to revisit agronomic practices for summer winter and spring maize after critically analyzing data on productivity constraints such as biotic and abiotic stresses, socioeconomic factors etc. in farmers' fields. Application of fertilizers including micronutrients based on the soil test reduces cost of cultivation. Supplementation with organic manure would improve nutrient use efficiency, soil health and reduce environmental footprints.

The production technologies of specialty corn are same as the normal maize. However, baby- corn cultivation differs due to planting of early- maturing prolific single- cross maize hybrid in higher plant population denisities with higher dose of nitrogen, detasselling or planting with male sterile hybrids, and harvesting unfertilized cobs within 1-3 days of silk emergence. It is all the more important to continuously generate information on date of sowing, nutrient-genotype interaction and plant density. Selection for shorter plant type opens up scope to increase population density for higher yield in different maturity groups. Further additional information need to be generated on the effect of mixed and inter-cropping on total productivity and benefit-cost (B:C) ratio.

Kharif maize in flood prone (diara) areas

Flood is a common occurrence in the middle of August in *kharif* maize, particularly in the eastern region of the country. With proper planning for flood- prone areas, this recurrent threat can be converted into an opportunity. This can be achieved by advancing planting of speciality corns like sweet corn, pop corn, baby corn and corn for green ears. Since monsoon breaks in the first week of June in the eastern region, it gives an advantage of planting maize 20-25 days earlier and harvested as green cob about 20-25 days earlier than fully mature grains. Additionally, soon after the harvest of green cobs, green stalks can be used as fodder and/or silage making. Baby corn and sweet corn can be canned at local level and exported to big cities, other states and also other countries.

Resource Conservation Technologies (RCTs)

These technologies offer opportunity for planting full -season maturity cultivars, reducing time between *kharif* harvest and *rabi* crop sowing , reducing cost on fossil fuel, improving organic-carbon, enhancing nutrient- use efficiency, and conserving moisture to help reduce pollution owing to fossil fuel burning while improving environmental safety. Normally farmers till their land using tractors several times after harvest of *kharif* crop. This takes about 15-20 days to prepare the land. In the process, field moisture is lost and farmers need to irrigate land before or immediately after sowing for proper germination. Zero tillage technology for planting full season maize hybrid results in higher yields owing to extending crop season and also lowering down tillage cost by Rs 3,000-4,000/ha and thus improves farm profitability. A special thrust was given by the National Agricultural Technology Project (NATP) to promote this technology in plain and peninsular regions of the country. Retention of residues and crop rotation practices in maize-based cropping system by crop diversification helped arresting soil erosion, improved soil organic carbon content, improved soil health and moisture conservation. Use of laser leveler also reduced requirement of irrigation water by 20-30 per cent. The adoption of site specific nutrient management practices and placement of the nutrients in root zone along with sowing by zero till cum fertilizer seed drill s further enhanced crop productivity and nutrient use efficiency (NUE). A large scale adoption is expected to improve profitability of farmers along with soil health, environmental safety and productivity. RCTs are gaining momentum in Indo-Gangetic region and in peninsular India.

Development of Maize Protection Technology

Maize protection technology should include ecosystem based measures to control insect- pests and diseases. Since pesticides kill pests and also natural enemies, their overuse harms farmers, consumers and environment. Utmost care should be taken to control major pests or diseases outbreaks, which threaten food security. Pesticide residues should not persist in (grain and fodder. Mismanagement and proliferation of obsolete stock piles of pesticides can harm beneficial soil- borne microbes, insect species and soil biota. The most desirable control measure is to develop cultivars resistant to insect -pests and diseases. It requires judicious and selective pesticides or biopesticides use for controlling pests. It is suggested that in maize no pesticides should be used to control insect- pests three weeks after germination or when the crop attains knee high stage. This is more pertinent in specialty corns. As far possible, biological and IPM control methods should be used for controlling insect pests. Farmers earn more if specialty corns are produced organically.

While screening large number of indigenous germplasm and imported ones, it was found that materials received from Caribbean region specially from Antigua had high degree of resistance to borers; when screening was carried out by artificial infestation. Similarly, germplasm were also screened under artificial inoculation or by growing in hotspots for diseases like leaf blights, stalk rots, PFSR, downy mildews etc. However, the process needs to be repeated.

Post Harvest Losses

Normally maize crop is harvested at 18-20 per cent moisture level. The grain has to be stored at 12 per cent moisture to protect them from storage grain pests and fungal infections. About 5 per cent losses are estimated during harvesting, threshing, winnowing, transportation, cleaning and storage. In fact, there are no proper grain storage facilities available in India. Thus, maize grains are damaged during normal storage due to hygroscopic nature of grains. Sun-drying, particularly during *kharif* season is not possible due to cloudy weather and high humidity, and maize grains become vulnerable to aflatoxins and weevil infestation. Since every farmer cannot afford to establish dryer and silos, there is a need to install dryers, and make available metal silos and storage facilities for farmers at community level.

Maize Processing and Value Addition

Maize grain serves as the basic raw materials for three major processes- dry milling, wet milling and alkali processing. The end products of these are being utilized as raw materials for other small, medium and large enterprises for production of more than thousand products which cater to the needs in one and other form in everyday life of the people. The products of dry milling are grids (40%), coarse meal (20%), germ (14%), fine meal (10%), flour (5%) and hominy feed (10%). The grids are being used for preparation of products like ready- to- eat snacks such as corn-flakes, porridges, wall paper paste, manufacturing of glucose by direct hydrolysis etc.

Although India is self sufficient in food production but the fact remains that large and vulnerable section of our society is suffering from macro and micro nutrient malnutrition due to one or other reasons. QPM offers a very good solution to the above problems in combination with other food materials, such as complimentary foods, health foods, snacks and savoury items. Convenience foods and specialty products are developed after alkali processing; which increases digestibility and palatibility of food. Complementary food are ready-to-eat food and can be prepared at home with QPM along with pulses, nuts, oilseeds, to feed newly born infants (of 6 months). Health food in the form of mix and other nutritious foods including ladoo, toffees, and chocolates can be specifically prepared for school children, pregnant and lactating women and also aged persons. Snacks and savory products are well suited for all age groups and contribute balanced nutrients. Large number of products have been developed and many are in the pipeline by Dr Rajendra Prasad Central Agricultural University, Pusa, Samastipur, Bihar, which can replace at least one or two products from the menu to secure nutritional security.

There is a huge potential to increase entrepreneurial skill for maize processing and value addition by involving local women and youth. Maize also offers good opportunity to develop small scale industries at the local level through alkali processing to develop maize-based products, like pasta, vermicelli, corn flakes, Jelly, ice cream cones, vermicelli (sewaian), functional foods and nutraceuticals. Dry milled QPM-based products like, roasted flour, dalia, suji, multi-grain flour, maize grid, namkeen products etc. offer immense promise for local youth and women. Primary processing of specialty corns like sweet corn, popcorn, babycorn at local level has potential to improve household job opportunities, profitability to farmers and most importantly engage them at the local level.

Maize starch is processed by wet milling processes and is used as an adhesive in textile and paper industry, thickener in food industry, filler in pharmaceutical industry, feedstock for manufacturing glucose, dextrose, ethanol, sorbital, nutraceutical industry, and number of other products. In past one decade many starch industries have been established in India which have increased maize demand.

Outscaling Innovations Involving Local Women/ Youth

Policies should be initiated for retaining youth in agriculture for effective dissemination of knowledge and out scaling innovations. Unemployed agricultural graduates of nearby villages should be encouraged and trained to be paid 'technology agents' to ensure efficient farm advisory services to farmers. A system in PPPP mode should be evolved to make aware technology agents of current research innovations and accomplishments. Also, technology agent should be supported by banks to provide credit to establish agri-clinics, including soil testing facilities to identify problem in farmers' fields and to provide needed advisory to use demand-driven productive resources such as seed of single cross hybrid resilient to climate change, good agronomic practices such as integrated nutrient management, water management, integrated crop management crop diversification with maize, pest management, conservation agriculture etc. to farmers to bridge productivity gaps.

The gender gap should be reduced by involving women in maize production, post- harvest management and value -chain to raise farm yields (20-30%), save on post- harvest losses, reducing malnutrition problem (12-17%), ensuring livelihood nutritional security, employment generation, environmental safety for sustainable intensification and income.

Local youth including school dropouts/uneducated should also be involved to support in needed services by the farmers after proper training as follows: 1) ***Input providers:*** To provide seeds, fertilizers, pesticides, biofertilizers etc. after proper training. They should be given certificates after training and only the certificate holders should be authorized to sell inputs; 2) ***Input producers:*** At village level, educate local entrepreneur to produce inputs such as biofertilizers, biopesticides, vermicompost, compost, soil amendments, production of cattles/ poultry feed concentrates, minimal mixture, complete feed etc.; and 3) ***Implement providers:*** To provide services and implements for tillage, seed drills, weed control, plant protection harvesters, dryers etc. on custom hire basis, specially to small and marginal farmers. All these would help to improve efficiency and engage local youth for providing services, and farmers would have more confidence in their own children/kith and kin.

Way Forward

Doubling of production is needed due to demand pull for meeting feed, food and industrial requirements and it can be achieved by comparative strong techno- economic competitiveness to export grains and seeds by developing climate resilient single cross hybrids suitable for *kharif* maize and by bridging gap between realized yield and potential yield. Maize production would require more than 7-8 per cent compound annual growth rate in yield which would be possible due to 80 per cent area coverage of *kharif* maize with single- cross hybrids, which would increase average productivity from 2.56 tones/ha to 5.0 tones/ha.

1. Improving Productivity

Thrust on genetic enhancement

- Recognizing productivity advantage of single-cross. maize hybrid including QPM emphasis should be given for strengthening pre-breeding activities for diversification of germplasm for exploitation of higher magnitude of heterosis with improved adaptability, introgressing resistance for biotic and abiotic stresses for enhancing genetic resilience to climate change.

- Integrating use of new tools and breeding techniques is required to save on time and to reduce breeding cycle for genetic enhancement such as, DH, MAS, GWAS, round the year nurseries and needed infrastructural facilities to develop hybrids for wider resilience to climate change.

- Farmers need to be sensitized about newly developed QPM single-cross hybrids available without yield penalty and be encouraged to use QPM as food and feed by poultry sector than normal maize. Since maize is the main cereal for feed, the quantity of normal maize used as feed can be reduced to half due to doubled biological value of QPM for true protein digestibility.

- A mechanism should be developed for upscaling and outscaling cutting - edge technologies including GM maize after ensuring biosafety measures to increase productivity and profitability.

Thrust on seed production of single cross hybrids

- Since maize can be grown in almost all parts of the country, a suitable area and season for developing seed production hub should be identified in each state with all the necessary infrastructural facilities, like seed- processing plants, cold chains, safe- storage facilities, uninterrupted power supply etc. in PPPP mode and made available to all producing agencies on rent to cut- down on cost of transportation for cheap availability of seed at the door step of farmers.

- A mission- mode approach on seed production of single -cross maize hybrids *is needed to bridge productivity gaps. A rolling* *plan* for seed production for at least 5 years should be prepared for outscaling better single -cross hybrids suitable for a specific region, jointly decided by a committee under the leadership of eminent scientist, seed sector representatives and a group of progressive farmers.

- Enabling policies should be in place to encourage private sector to invest *more in R&D to develop single cross hybrids* and to produce enough seed for *kharif* maize; considering vast area and seed replacement rate (SRR) to cover 70-80 per cent *kharif* maize area and phasing out old cultivars. The benefit of the subsidy need to be extended to the best hybrids, irrespective of notified or truthfully labeled (TL) developed by public or private sector.
- Necessary cold -storage facilities to establish seed bank in each region *should be developed as contingency measures to* manage maize- crop in *kharif* during the unforeseen situations.
- Necessary coordination and convergence is required among seed companies to take up production on the basis of maturity to avoid contamination in seed production area. Progressive farmers should also be involved in hybrid seed production with proper training.
- A mechanism already in place should be taken advantage of PPV&FR Act; providing protection to produce seed of public sector bred hybrids by private sector by paying 3- 5 per cent royalty negotiated on sale proceeds on exclusive/non-exclusive basis.
- Indian seed sector is very well established and has a potential to grow beyond boundaries of domestic market and enter global market such as Africa, SAARC countries, South East Asian countries. For this, needed statistics through Embassy are to be provided with enabling policies to help private sector to harness potential of global market.
- Quality testing laboratory should be established and equipped for testing transgenic seeds and QPM apart from normal seed.

Thrust on production and protection technologies

- Realization of the drastic effects of climate change in the last 10-15 years warrant bringing in resilience to biotic and abiotic stresses and also revisiting of agronomic recommendations towards sustainable intensification by adopting Conservation Agriculture to reduce cost on inputs, improvement in soil health, water- use efficiency, human nutrition and by linking integrated Farming System and crop diversification for improving production and farmer's income and reducing environmental foot print.

- Priorities should be given to contain biotic stresses by developing host plant resistance, IPM approaches, biological control methods, and enhancing farmers' income by lesser expenditure on purchase of chemicals.

2. Development of Maize Value Chain

- Maize value chain development should focus mainly in efficiency improvement, considering consumer demand which becomes driver for innovation and value- creation, leading to continuous improvement in food supply and benefits to consumers.

- There is a need to reduce gender gap involving women to raise farm yield by 20-30 per cent and reduction in malnutrition by 12-17 per cent .

3. Outscaling Innovations

- There exists a huge gap between potential and realized yield of maize. An innovative mechanism with PPPP mode has to be developed to disseminate production technologies involving local agricultural graduates as paid technology agents.

- In the absence of local entrepreneurship at the village level such as input providers, input producers, implement providers etc., the opportunities are hijacked by outsiders leading to exploitation and deprivation of employment to local youth; forcing them to migrate to cities for jobs.

- More investment is needed in maize R&D for upscaling and outscaling innovations. Such investment would yield higher returns in terms of productivity and economic growth in long-term than input subsidies.

4. Linking Maize Farmers to Market (LFM)

- It is important to improve market efficiencies by reducing price spread and raise producers share in consumers' rupee by stopping interference of middleman and encouragement of direct marketing for better profits to farmers. In this regard, e-Nam, ICT, print and electronic media offer new marketing opportunities.

- Farmers cannot hold on to maize- grains after harvest for long time due to their hygroscopic nature and are compelled to sell the produce as a result prices dip drastically. For better profit to farmers, the storage facilities at Tehsil level should be develop with PPPP mode for storage of produce; preferably graded and labeled signifying quality standards. This would help farmers to get credit against the receipt of the stored produce, and would avoid distress sales by them to realize better prices. This would also minimize storage losses and traders can lift produce from one place instead of door- to- door from farmers.

- A new mechanism should be developed in PPPP mode to make producer companies, self help groups, contract farming more farmer friendly under which buyers can provide farmers access to technology, quality inputs, more support in business skills, capital investment, credit facilitation, risk management and guaranteed better price. A comprehensive and progressive credit policy should be framed and implemented to free farmers from the clutches of money lenders.

- Engagement of rural - women and youth in village itself to sell specialty products such as frozen sweet corn, baby corn, roasted green ear, and packets of pop corn, ready-made QPM products, dry milling products, feed etc. at highway roadside or in nearby town/cities would ensure their livelihood security and income.

- There is considerable scope for the export of value -added dry- milling maize products and feed, certified organically produced specialty corn with good packaging, meeting quality of international standard. A strategy to LFM should be evolved for the participation of buyers across the country without restriction in movement of products and harmonization of tax laws/GST. Proximity to the national/international airports needs to be exploited for export of value- added products, feed etc. for better income.

5. Capacity Building

- There is a need to organize periodically capacity- building programmes for field officers, technology agents, other field functionaries involved in maize development programmes and vocational training programmes for farmers including women-farmers.

- Deployment of local youth and women require knowledge empowerment and guidance in business skills and to manage risk. Also, investment to establish unit for maize value -chain in a PPPP mode can play a very important role by forming self help groups (SHGs) of various stakeholders. Success of such an endeavour would depend on the integrity and competence of leaders involved with good professional support.

- Awards and incentives should be instituted to ensure progressive farmers, maize scientists, development workers including NGOs and private sectors for their outstanding work and they should be involved in decision making bodies.

6. Institutional Reforms and Enabling Policies

Planning maize research for development

- The maize research and development planning should be done involving all stakeholders viz., farmers, scientists, development and private sector personals, policy makers, ensuring their support and commitment.

- Research agenda should emerge from farmers fields' problems and are to be addressed taking into consideration Farmers- led innovation built on traditional knowledge. These need helping farmers to diversify maize- farming system from supply driven to demand driven for overall growth- increasing productivity, profitability and environmental safety.

- Crop diversification, mechanization, value- addition and reduction in food wastage should be encouraged in PPPP mode with supportive policies by the Government to act as coordinator/facilitator ensuring reliable and efficient supply of productive resources, services and delivery system, enrolling local youth by providing aggressive training for skill upgradation and creation of non-farm rural employment.
- Farmer's should be sensitized by policy initiatives taken by Central Government for doubling farmer's income and for conserving natural resources such as PM Irrigation programme, PM Agricultural Insurance, NFSM, RKVY, NHM, National Mission on Sustainable Agriculture, eNAM etc.
- Also, QPM maize should be procured and provided though public distribution system (PDS) in the states predominated by tribals and poor masses where maize is directly consumed as food to ensure their nutritional security.

Promoting Sustainable Intensification Practices

- The integrated resource conserving maize based farming system needs to be scaled up which has generated significant social, economic and environmental benefits to help farmers for increased production, productivity, improved livelihood, & income, while conserving natural resources, enhancing ecosystem services, adapting and mitigating effect of climate extremes under conditions of water scarcity and soil hunger.
- There is a need to review current support for adoption of Resource Conservation Technology sustainable practices to maize with a view to eliminate 'perverse subsidies' that encourage harmful practices, such as over use of fertilizers, pesticides, water, leading to losses to genetic resources and natural resources.

Acknowledgements

With deep sense of gratitude, I acknowledge the contributions made by the Rockefeller Foundation for the help in the establishment of first AICRP with multilocation testing, multi-disciplinary concept, financial assistance, laboratory equipments along with scientific manpower – R.W. Cummings, E.W. Sprague, Coordinator (RF), B.L. Rainfro, W.R. Yoing, Bill Wright, Johnson Duglus. I am thankful to CIMMYT for providing required germplasm including QPM and guidance through E.W. Sprague, R.L. Paliwal, S.K. Vasal, Shivaji Pandey, B.M. Prasanna, Carlos De Leon and Gunzalo Granados and for their active collaboration in Indian programme. I duly acknowledge the Indian Council of Agricultural Research (ICAR) for establishing first All India Coordinated Research Programme on maize covering all maize growing states of country with financial, technical, MFRA-structural support and required manpower.

I shall ever remain thankful to the contributions made by Dr. N.L. Dhawan, the first Coordinator, in the beginning of the programme, to establish maize centres, developed needed infrastructural facilities required for maize research and creating a school around him to develop quality manpower, especially two World Food laureates - Dr. S.K. Vasal and Dr. S. Rajaram. Dr. Joginder Singh provided firm footing to the program along with Associate Coordinators Drs. V.H. Shah, M.M. Payak and S.M. Chatterjee for identifying hotspots and for developing production technologies. The contributions of breeders like Drs. S. Vittal Rao, S.M. Ali, A.S. Khehra, B.S. Dhillon, T.P. Singh, Rameshwer Singh, S.J. Patil, R.S. Rathore, K.T. Pandurangegowda and V.P. Mani are worth mentioning as they have made inferable contributions for the development of maize technologies. Some of the farmers like B.P. Pandya of Tannage Club, Dahod, Gujarat; Data Ram Mishra of Masina Beej Nigam (Bihar) and Dr. B.R. Barwale, Mahyco, Jalna made significant contribution to outscale innovations.

Enabling policies initiatives taken by Dr. R.S. Paroda, the then Secretary, Department of Agriculture Research & Education and Director General, ICAR to develop Public-Private-Partnership for unrestricting flow of seed of public sector hybrids, encouraging regional cooperation through TAMNET, strengthening hybrid program under new seed policy, production of public hybrids by private sector on royalty basis. Also PPV&FR Authority and National Biodiversity Authority has helped a great deal in promoting the sector to the concept of production and marketing of single cross hybrids which help to increase maize production and productivity significantly.

September 10, 2017 **(N.N. Singh)**

Recent TAAS Publications

- Stakeholder Interface on GM Food Crops - Recommendations, May 19, 2011.
- TAAS Foundation Day Lecture on "Harnessing Knowledge for India's Agricultural Development" by Dr. Uma Lele, August 12, 2011.
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- National Dialogue on Efficient Management for Improving Soil Health - New Delhi Soil Health Declaration - 2015, September 28-29, 2015.
- Regional Consultation on Agroforestry: The Way Forward - New Delhi Action Plan on Agroforestry 2015, October 8-10, 2015.
- National Dialogue on Innovative Extension Systems for Farmers' Empowerment and Welfare - Road Map for an Innovative Agricultural Extension System, December 17-19, 2015.
- Round Table Discussion on Promoting Biotech Innovations in Agriculture and Related Issues - Proceedings & Recommendations, August 4, 2016.

Brief Resume

Dr. N.N. Singh, born on 20th August 1943 in village Pali, Gorakhpur (Uttar Pradesh), joined the AICRP (Maize) in 1964 and to the post of Project Coordinator/Project Director at Directorate of Maize Research (now Indian Institute of Maize Research) in 1994. As a leader of the National Maize Programme, he has been instrumental in promoting maize germplasm, development of three way and single cross, normal and quality protein maize hybrids and other suitable maize cultivars in different maturity groups including sweet corn, pop corn, baby corn etc. for *Kharif* and *Rabi* seasons; some of which are still popular with the farmers and occupies large areas of the country. Consequently, there was a marked increase in area, production and productivity of maize.

Dr. Singh encouraged and nurtured inter institutional linkages with National and International Research Institutes and Public Private Partnership for the overall improvement of maize. He has over 100 research papers in the international and national journals of repute, several chapters in different books besides popular articles. With over 41 years of experience in research & teaching at IARI, New Delhi, he supervised 13 Ph. D and 4 M. Sc. students. In recognition of his academic and research work, he was elected as Fellow of National Academy of Agricultural Sciences. Besides, he served as President, Vice-President and Secretary of many reputed national societies/trusts/programs including Chairman, QRT and RACs, and Members of various Boards and Governing Body of ICAR and CIMMYT Maize Program. For his outstanding contribution in maize R&D, he was awarded by Seed's Men Association of Andhra Pradesh and Seed Association of India, and also honored by many agricultural universities and organizations in the country. He has visited 28 countries as the Leader of Maize Programme and initiated Maize On-farm Research Programme in 3 Latin American countries (Honduras, Equador, El Salvador).

During his tenure as Vice Chancellor, Birsa Agricultural University, Ranchi, he developed model infrastructure for research and education in agriculture, and thus, the University is accredited with A* Grade by the Indian Council of Agricultural Research (ICAR) and Indian Council of Forestry Research and Education (ICFRE) and has become one of the few agricultural universities acclaiming this distinction. He was also instrumental in establishment of three colleges supported by the state government. Besides substantial physical progress in the development of infrastructure, there has been significant intellectual progress in teaching and research standards. He is also instrumental in establishing 14 new Krishi Vigyan Kendras during his tenure. The pace of development was so fast that the university is now one of the consortia partners of Rice Knowledge Management Portal of ICAR. For exceptionally outstanding contribution to maize research R&D, the Confederation of Horticulture Association of India (CHAI) has conferred on him "Life Time Achievement Award 2017" and Honorary Fellowship (FCHAI).

Through his dedication and devotion to cause of agricultural research and his outstanding personal leadership and managerial acumen, he has contributed immeasurably to the National Agricultural Research System. Even at this stage, Dr. Singh has incredible stamina and tremendous zeal for work. Currently, he is serving to link society with science as Secretary, Trust for Advancement of Agricultural Sciences (TAAS).