मक्का अनुसंधान निदेशालय
Directorate of Maize Research
(भारतीय कृषि अनुसंधान परिषद)
(Indian Council of Agricultural Research)
पूसा परिसर, नई दिल्ली ११००१२
Pusa Campus, New Delhi 110 012
www.maizeindia.org

"The last two decades saw the revolution in rice and wheat, the next few decades will be known as maize era"

- Noble Laureate Dr Norman E. Borlaug
Father of Green Revolution

DMR Vision 2030

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PRINTED : June, 2011

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Published by the Project Director, Directorate of Maize Research, Indian Council of Agriculture Research, Pusa, New Delhi- 110 012. Laser typeset and printed in India at M/s Alpha Printographics (India), WZ-572/O, Naraina Village, New Delhi 110 028

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.

Maize (*Zea mays* L.) is the third most widely distributed crop of the world being grown in tropics, sub-tropics and temperate regions. It was stated by the Father of Green Revolution, the Noble Laureate Dr. Norman E. Borlaug, "*The last two decades saw the revolution in rice and wheat, the next few decades will be known as maize era*". In India as per the latest report, maize area, production and productivity is estimated to be 8.3mha, 20.23mt and 2.4 t/ha, respectively in 2010-11 (DACNET). This was possible primarily due to high genetic potential of the existing genotypes of various maturity groups in different growing conditions. The Directorate of Maize Research (DMR), New Delhi has been conducting research in the development of improved single cross hybrids and farming techniques, and their promotion in the country. Developing single cross hybrids, genotypes for intensive agricultural systems, value addition and genetic enhancement through molecular tools are some of the existing opportunities available for maize improvement.

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.

24th June, 2011
New Delhi

(S. AYYAPPAN)

Secretary, Department of Agricultural Research & Education (DARE)
and Director General, Indian Council of Agricultural Research
Krishi Bhawan, Dr. Rajendra Prasad Road,
New Delhi 110014

Preface

Maize crop has an important place in the food grain scenario of our country and is the third most important versatile food grain crop due to its importance in food, feed, specialty corn, starch, etc. for both domestic consumption as well as export. Being C_4 plant, it is more resilient to changing climate.

All India Coordinated Maize Improvement Project (AICMIP) was the first in the series of coordinated programmes of the country started in 1957 and was upgraded as Directorate of Maize Research in January, 1994. High yielding single cross hybrid (SCH) seeds with improved package of practices boosted maize production. Consequently, it has registered highest growth rate of 6.4 per cent (2007-2010), the highest among all other food crops, surpassing the 4 per cent growth rate for agriculture and 4.7 per cent for maize set by Planning Commission. This has been possible owing to the concerted efforts of the scientists of Directorate of Maize Research and AICMIP/SAUs/ICAR Institutes/farmers of the country. DMR and AICMIP/SAUs/ICAR Institutes are committed to development of single cross hybrids for sustained growth of this commodity through strategies mentioned in the document.

It is my proud privilege to express sincere gratitude to Dr. S. Ayyappan, Secretary, DARE and Director General, ICAR for invaluable guidance in promoting maize research in India. I am also grateful to Dr. S.K. Dutta, Deputy Director General (Crop Sciences) for the consistent support, encouragement and timely suggestions for strengthening maize research. I am always thankful to Dr. R.P. Dua, ADG (FFC) and Dr. J.S. Sandhu, ADG (Seeds)

for their continuous support to Directorate of Maize Research as and when required.

I consider it a moment of exhilaration while expressing thanks to all the scientists of the Directorate for their concrete contributions in preparation of the '*DMR Vision 2030*'. My special thanks are due to K.S. Hooda, Chikkappa G.K., Bhupender Kumar, R. Ambika Rajendran, Pradyumn Kumar and S.L.Jat for their contribution in compilation of this document. I have no words to express deep sense of gratitude and sincere thanks to Dr. Sain Dass, former Project Director, DMR, presently President, Indian Maize Development Association (IMDA) who has critically reviewed this document and gave his invaluable input. The administrative support provided by Dr. A.K. Singh, I/c Account & Finance Officer; Sh. Rohtash, Administrative Officer and Sh. K.S. Chauhan, Assistant Administrative Officer is also duly acknowledged.

24th June, 2011
New Delhi

(R. Sai Kumar)
Project Director
Directorate of Maize Research
Pusa Campus, New Delhi 110012

Preamble

The systematic research on maize was initiated through the establishment of erstwhile All India Coordinated Maize Improvement Project (AICMIP). This was the first in series of the coordinated system of the country. Recognizing the changed scenario of newly emerging food habits, consumption patterns, increasing population pressure, limited natural resources and the enhanced industrial requirements of the maize in India, AICMIP was upgraded as Directorate of Maize Research in January, 1994.

In recent years, maize has turned out to be a commodity with impressive growth rate and has contributed immensely to the national economy. It will continue to play an important role in food, nutritional and livelihood security of the country. It is, therefore, necessary that we widen the maize production technology for favourable as well as marginal environments, which will be relevant to socio-economic development of the farmers and to the rural environment as a whole.

'*DMR Vision 2030*' document recounts key challenges and opportunities in the maize sector in the next two decades for developing appropriate strategies and a roadmap to glorify the role of Directorate of Maize Research in shaping the future of the maize research growth and its development.

Contents

Maize Scenario – National and International

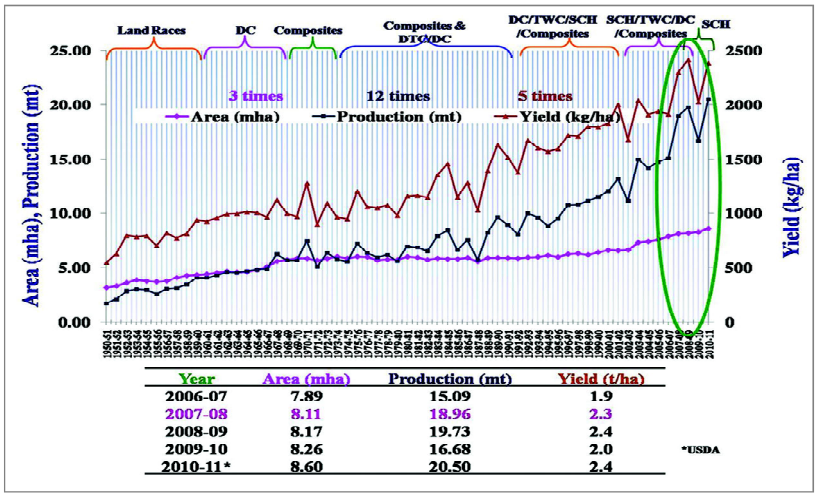
Maize (*Zea mays* L.) is a versatile crop grown in largest number of countries (170) in the world. Its cultivation is done in different agro-climatic conditions from sea level to >3000m amsl. Among the food cereal crops, maize has the highest genetic potential, production and productivity. Thus, it is called as *Cereal Queen* . The area, production and productivity of maize in the world is around 162mha, 820mt and more than 5t/ha, respectively (USDA, 2011). USA and China together account for nearly 40 per cent of total area and 60 per cent of total world production (Table.1). The higher productivity in USA is due to adoption of single cross hybrids, favourable climatic conditions, long duration and high input. Further, the USA has 90 per cent area under Bt corn which has enhanced the production of maize in that country. Presently, India ranks 4th in area and 7th in production of maize at world level. For the last ten years the intervention of biotechnology has led to quantum jump in maize productivity in USA, and is close to 10t/ha. In India the productivity of maize continued to

Table 1. Global maize scenario in 2010-11 (Total countries >170)

Country	Area(mha)	Production (mt)	Yield (t/ha)
USA	32.9	316	9.59
China	32.5	173	5.33
EU-27	7.9	55.5	6.94
Brazil	13.3	55	4.14
Argentina	3.2	24	6.88
Mexico	6.6	21.5	3.26
India	8.6	20.5	2.40
South Africa	2.9	12	4.14
Ukraine	2.6	11.9	4.50
Canada	1.2	11.7	9.74
World	162.3	820.6	5.06

Source: Production, Supply and Distribution (PSD) Database, June 9th, 2011 http://www.fas.usda.gov/psdonline/

be around 1t/ha for many years and the area remained stuck around 6mha. The work on single cross hybrid research was initiated with launching of hybrid project in 1989-90. But, the work on single cross hybrid was accelerated in the last five years. As per the latest reports by USDA; the area, production and productivity of maize in India are 8.6mha, 20.5mt and 2.4t/ha, respectively in 2010-11 (Fig.1). The focused research on single cross hybrid across the country has helped in increasing production and productivity of maize. Cultivation of single



Year	Area (mha)	Production (mt)	Yield (t/ha)
2006-07	7.89	15.09	1.9
2007-08	8.11	18.96	2.3
2008-09	8.17	19.73	2.4
2009-10	8.26	16.68	2.0
2010-11*	8.60	20.50	2.4

*USDA

Fig. 1. Area, Production and Productivity trend of maize in India

cross hybrids has become relatively more remunerative leading to expansion in non-traditional areas. Maize contributes 9 per cent to the food basket despite being cultivated as rainfed crop in 80 per cent of its area. Among the major cereals, maize has recorded highest growth rate in recent past (Fig. 2). India s maize production has increased nearly 12 times from a mere 1.73mt (1950-51) to 20.5mt (USDA, 2011) (Fig. 3 and 4). Maize is an important crop having multiple types *viz.,* grain, QPM, sweet corn, popcorn, baby corn, high

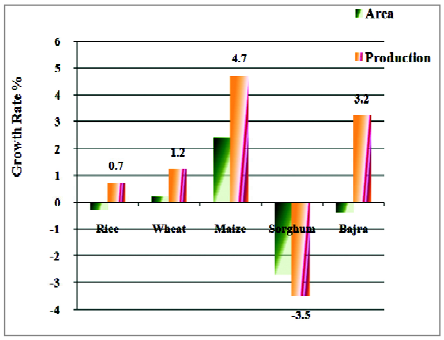


Fig. 2. Highest growth rate of maize (1995 to 2010)

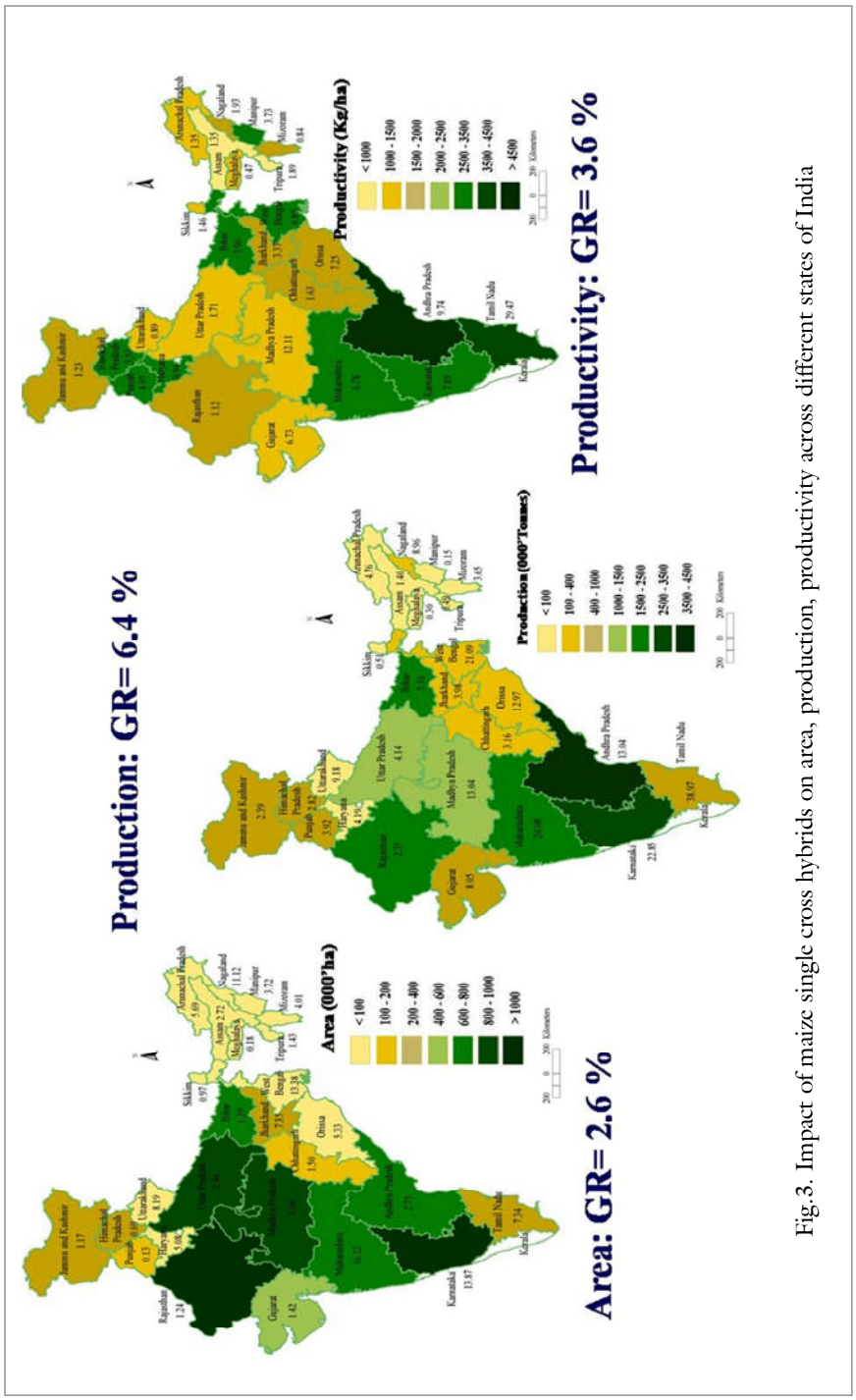


Fig.3. Impact of maize single cross hybrids on area, production, productivity across different states of India

oil and fodder, *etc*. It is mainly used for food, feed and fodder. It also serves as an important raw material for starch industries which finds its applications in thousands of products. In USA, maize is being used in manufacturing of over three thousand five hundred products, whereas in India, it is being used in manufacturing of over one thousand products. With the increasing urbanization, purchasing power and changing food habits, the current utilization pattern has changed. In the past, maize was used as staple food but now lion s share goes to poultry and livestock sector. Further, maize, being C_4 plant is a solution to climate change, rising temperature during winter season and lowering water table in rice belt of India.

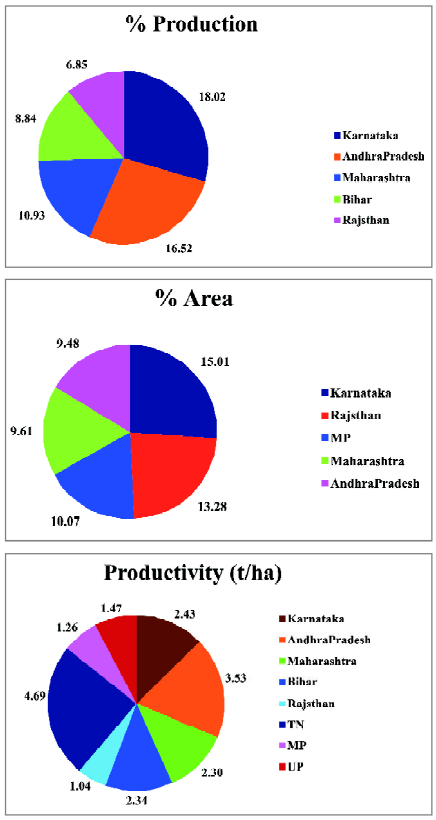


Fig. 4. Area, production and productivity of maize in leading states of India (2009-2010)

Maize in Indian economy

Maize cultivation, marketing and value addition generate more than 1000 million man days in the country. It contributes more than 9 per cent to the national food basket and provides nutritious and risk free green fodder to the livestock from rainfed (~80 per cent area) and low input conditions. Maize contributes 400 billion rupees towards national gross domestic product (GDP). India earns foreign exchange worth rupees 2,500 to 3,000 crores annually by exporting only maize grain of 2.5 to 3.0 million tonnes. Besides, a large number of value added products like starch and its derivatives and baby corn, *etc*. are also being exported annually. Thus, the earning is much more than the money spent on research. So, maize is playing and will continue to play a very important role in Indian economy.

Current maize utilization in India and world

Maize contributes up to 50 per cent of the total daily calorie requirement of people consuming maize as staple food. In the past, 95 per cent of maize produce was utilized as food in India. But now, maize consumption pattern has changed. Presently, maize is being used mainly for feed (63 per cent), food (23 per cent), starch industries (12 per cent), seed, breweries and miscellaneous uses (2 per cent) in India (Fig. 5). Utilization of maize as feed in India is at par with world but per cent share in food and industrial does not match. The higher percentage (22 per cent) of maize used in industries in the world as compared to India (12 per cent) is due to shift of USA-maize produce towards bio-fuel extraction. Now maize has attained a status of industrial crop in the world because 83 per cent of maize in world and 76 per cent of maize in India has its application either in feed or other industrial sectors.

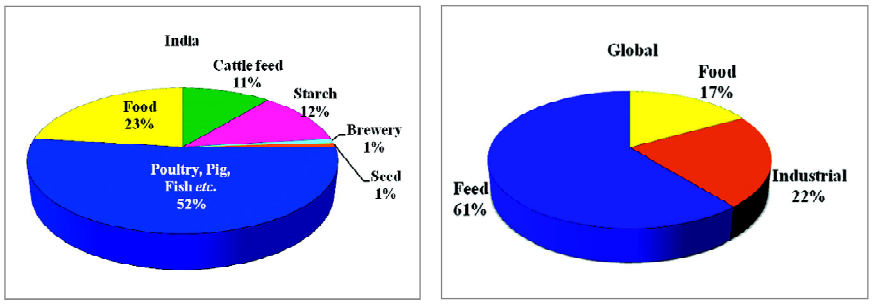


Fig. 5. Current utilization pattern of maize in India and world

Maize is used as raw material in several industries *viz*., starch, oil, pharmaceuticals, textile, paper, film, tyre, alcoholic beverages, food sweeteners, cosmetics, packing, bio-fuel, *etc*. Owing to increasing growth rate of poultry, livestock, fish, wet and dry milling industries in India, maize demand will continue to increase in the years to come.

Apart from food, feed and fodder, maize is also grown for many other purposes *viz*., Quality protein maize (QPM), sweet corn (SC), baby corn (BC), popcorn (PC), waxy corn (WC), high oil (HO), amylo-maize *etc*.

Salient research achievements

Till 10th Five Year Plan, the major emphasis was on the development of open pollinated varieties and multi-parent hybrids of maize in India. Consequently, the production and productivity of maize remained stagnant for many years in the country. The impact of adoption of single cross hybrids in USA, China and many other countries has already been witnessed. SCHs are most productive having wider adaptability to new set of cropping systems and management practices. Encouraged by these tangible results, since 2006 the Directorate of Maize Research, AICMIP, SAUs and ICAR Institutes focused their research strategy on single cross hybrid development. As a result of focused research on single cross hybrids development and their adoption, maize production and productivity have been continuously increasing. Since then, 45 high yielding single cross hybrids for different agro-ecological conditions of the country have been developed (Fig. 6). With the coverage of about 20 per cent of the total maize area under single cross hybrids, India has registered a spectacular increase of 35 per cent and 24 per cent on maize production and productivity, respectively during 2006-11. Success stories of increasing maize productivity in many states have been

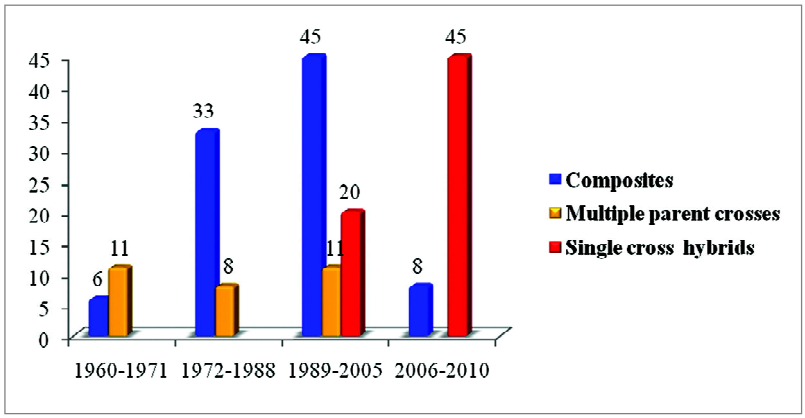


Fig. 6. Maize cultivars released in India

demonstrated. Andhra Pradesh has recorded per day productivity more than USA in zero tillage maize cultivation during winter season. By just covering only 10 per cent area under single cross hybrids, Rajasthan has doubled its productivity. With the adoption of this technology, the growth rate of area, production and productivity of maize in almost all states is on increasing trend. The coverage of maize area to 100per cent under single cross hybrids will double the production in no time and increase the farm profitability.

Prospects and projections of maize

The future of maize is bright because the growth rate of maize consumption sectors is continuously increasing (Table 2). Maize has great potential and prospects as food, feed, specialty corn, starch, *etc*. for both domestic consumption as well as export. The projection and production will match in the coming years with the speed of technology dissemination. The current production of 20.5mt is only with 25 per cent technology adoption by the farmers of India. Maize demand and the production will continue to increase because of available technology and prospective industries. In

Table 2. Prospects of maize utilisation

Sectors	Purpose	Annual Growth Rate (per cent)
Food	Grain	2
	Specialty corn	20
	Formulated food	10
	Dry milling	5
	Wet milling	7
Feed	Feed growth	11
	Poultry broiler	9
	Poultry layer	7
	Dairy	3.4
Brewery	Beer consumption	17.5
Industrial purposes	Higher prices due to diversion for ethanol	Competitive prices

coming years, maize based feed, starch and its allied industries are going to expand in India. The production of maize is projected to be 45 million tonnes by the year 2030 (Fig. 7). The projected demand for maize will be met either by technological intervention or by bringing more area under maize cultivation. The technological interventions are adoption of high yielding single cross hybrids (SCHs) seeds, biotechnological

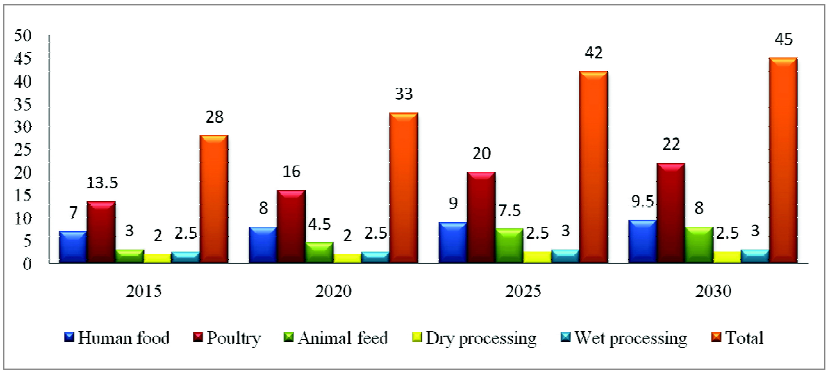


Fig. 7. Projected utilisation of maize by 2030

intervention and improved package of practices in different agro-ecological regions of the country. The additional land can be brought under maize cultivation in states *viz.,* Madhya Pradesh, Rajasthan, Tamil Nadu, Gujarat, Andhra Pradesh, Maharashtra, Punjab, Karnataka, West Bengal, Orissa, Chhattisgarh, Jharkhand, Uttar Pradesh and north east region. In these states there is increasing pressure on natural resources like declining water table and effects of climate change. In these situations, maize offers a better chance to overcome these problems. Further, maize has the potential to capture some areas from coarse cereals, *Rabi* rice in peninsular India as well as upland rice and wheat in eastern India on account of its better crop returns.

The present growth rate of maize (8.94 per cent) production is much more than its consumption (5.0 per cent). Planning commission set 4 per cent growth rate for agriculture and 4.7 per cent for maize, however, maize achieved 8.0 per cent growth rate, which is highest among all other food crops (2006-2010) and also much higher than the target set in 11th Five Year Plan. India has great potential to export grain, feed, seed and specialty corns (baby corn, sweet corn) due to low cost of production and less freight charges. This will help to earn foreign exchange, generate employment and engage rural masses. Adoption of

SCH technology has contributed significantly in achieving this target and consequently, India became a net exporter with annual exports of 2.5 to 3 million tonnes since 2008-09. Thus, maize has the potential to meet increasing future demand of the country and support the need of neighbouring countries also.

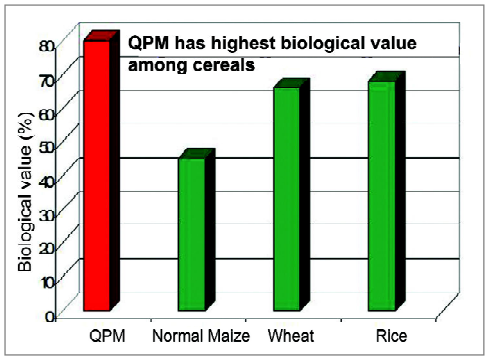


Fig. 8. Biological value of QPM

In India, 87 per cent maize is directly or indirectly used as food by human and feed by vast growing poultry/ livestock population. Large number of people in India and other developing countries use normal maize as their staple food, suffer from protein malnutrition. The prices of meat, egg, milk and their products have gone higher and for those who cannot afford them, the quality protein maize (QPM) is an alternative nutritive food. QPM is nutritionally superior to normal maize and is the cheapest source of protein. Since, the biological value and digestibility of QPM (Fig.8 & 9) is higher than normal maize, this will provide low cost nutritious food/feed and is a solution to food and nutritional security.

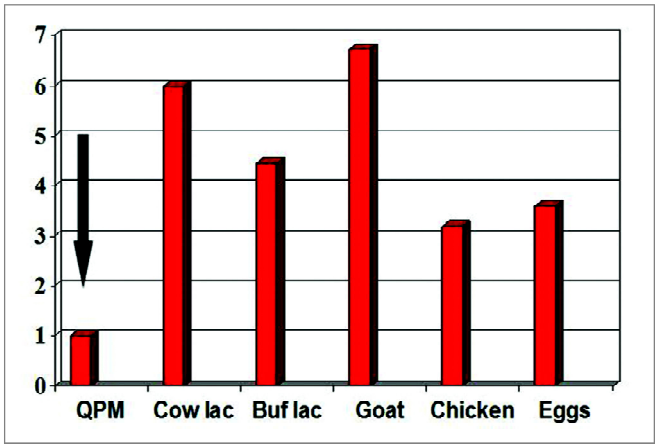


Fig. 9. Cost of production per unit protein

Future strategies for increasing maize production

The focused research on single cross hybrids by Directorate of Maize Research and AICMIP/SAUs/ICAR Institutes will be continued as it is a remunerative technology. Further, to strengthen the SCH technology, development of suitable germplasm, agro-techniques, seed production system will be prioritized. The other strategies will be making maize cultivation more profitable by bringing more area under hybrids from the non-remunerative crops as well as non-traditional areas. This is possible with the opportunities existed as Noble Laureate Dr Norman E. Borlaug, the Father of Green Revolution stated 10 years ago that *The last two decades saw the revolution in rice and wheat, the next few decades will be known as maize era"*. To achieve the targeted production for the year 2030 (Fig. 6) the following strategies will continue to be in practice.

1. **Promotion of seed industries** Large demand for single cross hybrid seed is an opportunity for seed industry growth. Promoting self help groups, small indigenous seed companies, encouraging MoUs of the public sector hybrids and participating in Public Private Partnership (PPP) will help to meet the required demand of seed in the country. Adequate seed production taken at sites will help in making timely availability of seed to the farmer. This will increase the area under hybrid cultivation. The cost of single cross hybrid seed production in India is lowest in the world and therefore, after meeting the requirement of the country, the seed export to neighbouring countries will be profitable to the Indian farmer and seed industry. Revival of seed production chain to facilitate timely availability of seed on large scale will continue to receive top priority.

2. **Mitigation of regional imbalances**: Himalayan and sub-Himalayan areas in north and north-east are temperate which can impart a productivity advantage for maize cultivation. There is low productivity in north-east due to cultivation of low yielding open pollinated varieties (OPVs). The replacement of OPVs with SCHs in these areas need to be addressed on priority as the north western, north eastern and sub-Himalayan region are suitable for hybrid cultivation.

3. **Conservation technologies and cropping system research for reducing the cost of cultivation**: Research on the integrated crop management practices for different agro-climatic conditions can help to realize high yield potential of the SCHs. The mitigation of losses due to abiotic stress including climatic change need to be addressed with the introduction of improved resource use efficient conservation technologies.

4. **Promotion of specialty corns and their value addition for livelihood security:** With the increase of urbanization, change in food habit and the improved economic status, specialty corn has gained significant importance in *peri*-urban areas of the country. The demand of baby corn, sweet corn and popcorn is increasing every year. The development of suitable hybrids and their production technology for specialty corn will further be strengthened. The popularization of processing products of specialty corn maize for ensuring the livelihood security of rural masses and promotion of small scale entrepreneurship will receive greater attention (Fig. 10 & 11).

Fig. 10. Value added products of baby corn for livelihood security

Fig. 11. Value added products of QPM for food and nutritional security

India s research and development strategies in maize improvement have to be achieved for sustaining economic viability with immediate socio-economic impact for the benefit of the farming community. It will certainly be possible to make this crop the most competitive for different agro-climatic conditions of the country.

DMR 2030

All India Coordinated Maize Improvement Project (AICMIP) was the first in series of coordinated programmes of the country in 1957 and was upgraded as Directorate of Maize Research (DMR) in January 1994. DMR is continuing to organize, conduct, coordinate and generate technology for continuous enhancement in production and productivity for meeting the ever increasing demand of human food, animal feed and industrial utilization and for other value-added products.

Mission

Enhancing the productivity, profitability and competitiveness of maize and maize based farming systems with economic and environmental sustainability

Vision

To bring about a rapid growth in the food, feed and industrial application of maize and maize based products, leading to generation of wealth, employment in farming and industrial sectors, would usher prosperity for all those who are directly or indirectly associated with maize cultivation and utilization.

Mandate

As food for man and feed for animals, maize is one of the most important crops in India and world agricultural economy. It has highest yield potential than any other food cereal. To meet the increasing demand several measures are to be taken with the following mandate:

- To carry out basic, strategic, contractual and applied research aimed at enhancement of quality and productivity through collaborating with national and international research organizations.
- To serve as a core centre for making availability of germplasm and provide consultancy services.
- To conduct and coordinate multi-disciplinary and multi-location research to develop, identify and transfer ecologically sound and economically viable maize technologies for varied agro-ecosystems.

Harnessing Science

To meet the increasing demand of maize for food, feed and industrial sectors, there is need to integrate conventional and novel tools of molecular biology to increase the per unit gain. Like other crops, maize is also facing several challenges from various biotic and abiotic stresses. These stresses will be managed by identification and introgression of novel genes and improved management practices.

1. Germplasm development, enhancement and exchange

Superior germplasm is the strength of any crop improvement programme. Identification of elite lines from the germplasm is essential for improving all types of maize with respect to its yield potential, quality attributes, resistance to all kinds of stresses. Superior germplasm can be acquired through exploration from various exotic and indigenous sources. Exchange and sharing of germplasm through national and international collaboration will improve the quality and the diversity in germplasm. Germplasm development can be achieved by (i) broadening genetic base of source materials as a long term strategy (ii) grouping of germplasm based on genetic potential (iii) screening germplasm for biotic and abiotic stresses (iv) making cross combinations and production of best hybrids. The material developed will be utilized in several conventional and molecular breeding programmes.

2. Development of single cross hybrids

Increasing production and productivity of maize is possible with development of single cross hybrids of normal maize, quality protein maize (QPM), baby corn, sweet corn, popcorn, *etc*. targeting different cropping systems in various agro-climatic regions of the country.

3. Biotechnological interventions

Certain limitations of conventional breeding can be overcome by using biotechnological approaches. Novel techniques like marker assisted selection (MAS), gene pyramiding, allele mining, transgenics, *etc*. for providing solution to problems like drought, weeds, diseases and insects. These techniques will also be used for biofortification of maize to improve its nutritional quality.

4. Nutritional enhancement

Normal maize needs nutritional enhancement. Several people, particularly from developing countries, derive their protein and calorie requirements from maize. Owing to growing middle to upper class population in India with increasing awareness towards consumption of healthy foods there is a requirement to increase biological value of normal maize. This can be achieved by improving the nutritional profile of maize endosperm, which can ensure more bio availability of protein to human and animals. Therefore, nutritional enhancement of maize will be a formidable challenge and hence achieving this would be one of the research priorities.

(i) Specialty corn Protective food and feed

Specialty corns have several health benefits along with a delicious taste of their own. Specialty corn types (QPM, sweet corn, popcorn and baby corn) are rich in essential nutrients. Further, nutritional improvement using traditional and modern approaches can be the best option for ensuring nutritional security virtually at no additional cost. Biofortification for traits like protein quality and vitamin A, *etc*. will increase levels of several micronutrients to meet daily requirements.

(ii) Specialty corn- Industrial profitability

Specialty corns *viz.,* quality protein maize, baby corn, sweet corn, waxy corn, high amylose corn, high oil corn *etc*. has wider industrial applications as they possess unique market demand for utilization by corn food, feed and processing industries. Currently,

there are limited commercial quantities of these corn types available in the market. In future, there will be significant growth of market demand for these specialized corn products. Alteration in starch, amino acids and oil content of corn can better meet the needs of poultry, livestock, food industry and other industrial users. Modifications of ordinary corn to specialty corn using scientific approaches can improve yield potential and quality parameters. Industrial advancement leads to income generation and thereby livelihood improvement. Measures such as contract farming, setting up processing units, ensured market, interaction between public and private sector, incentive based value chain will increase production. Low cost of production in India will further promote export of specialty corns and their value added products.

Strategy and Framework

The following strategies have been envisaged to achieve the vision 2030 of Directorate of Maize Research for food, feed and nutritional security of the country (Annexure I).

1. Germplasm development and its enhancement

- Exploration and procurement of maize germplasm world over for maize improvement and its enhancement.
- Evaluation and maintenance of the germplasm.
- Classification and identification of germplasm based on type, colour, texture, maturity group, *etc*. for their further use.

2. Development of single cross hybrids

- Evaluation of inbred lines possessing desirable gene(s) for resistance to various biotic and abiotic stresses.
- Identification of seed and pollen parents with desirable traits.
- Development of single cross hybrids with desirable lines suitable for different production ecologies of normal, QPM, baby corn, sweet corn, pop corn, waxy corn, high amylo-maize, high oil, biofuel, *etc*.

3. Specialty corn database development

- Collection of data on area, production and productivity of various specialty corn like QPM, baby corn, sweet corn, *etc*.
- Import-Export status, potential in domestic and international market.

4. Molecular breeding for accelerating breeding programme

- Integration of molecular markers as a tool in conventional breeding programme.
- Identification, mapping, isolation, characterization and validation of gene(s) of economic importance.

- Development of transgenic maize for herbicide, drought, pest and disease tolerance.
- Increasing shelf life of specialty corn quality traits through antisense RNA technology and other biotechnology intervention.

5. Integration of frontier areas with conventional technologies

- Use of double haploid technology in inbred lines development.
- Integration of Geographical Information System (GIS), Geographical Positioning System (GPS) and meteorological data for estimation of area, production, productivity and for forecasting of disease and pest incidence.

6. Breeding for management of natural resources and climate change

- Breeding for input-use efficiency.
- Development of SCHs tolerant to various biotic and abiotic stresses.

7. Development of agro-techniques

- Development of package and practices for newly developed hybrids and their parents.
- Long term conservation agriculture based resource conservation technologies (RCTs) to reduce cost of production, abiotic stress and to enhance the farm profitability to sustain soil health and quality in maize based cropping systems.

8. Biochemical approaches

- Identification of maize genotypes for high bio-fuel production.
- Identification of inbreds/hybrids for high carotenoids.
- Nutritional evaluation for biological value through feeding trials.

9. Identification of sources of resistance to biotic and abiotic stresses

- Identification of stable sources of resistance to biotic stresses.
- Identificaiton of sources of tolerance to abiotic stress.

10. Disease management strategies

- Management of diseases through genetic, cultural, biological and chemical approaches.

11. Minimizing mycotoxin contamination in grains

- Identification of potential biocontrol agents (BCA) in maize.
- Management of aflatoxin through cultural, biological and chemical methods.

12. Insect pest management

- Development of integrated pest management following habitat management, biopesticides and use of pheromones, *etc*.
- Storage pest management through prophylactic, curative measures and improved storage structures.
- Identification of phytochemicals responsible for antibiosis and antixenosis.

13. Technology transfer

- Demonstration of promising technology for enhancing the income of the farmer through conducting trainings,FLDs *etc*.

14. Institution and policies

- Formulation of Institute policies to encourage the scientists by providing all the facilities.
- Promotion of team spirit among the scientists.

15. Education and human resource development

- Strengthening national and international collaboration.
- Mission mode and need based training.

Epilogue

Maize is globally most important crop with the highest genetic potential, production and productivity among the cereal food crops. India ranks 4th in area and 7th in production of the maize in the world. It is the third most important food grain crop of India which contributes more than 9 per cent to the total food basket. Despite, 80 per cent rainfed crop, its productivity is more than rice which is grown almost under assured irrigated conditions. It is mainly grown for food, feed and industrial purposes. It is the crop with diversified uses and many types grown in diverse climatic conditions in almost all parts of the country. To meet the country s future projected demand and to support the export the DMR has focused research on single cross hybrid. Single cross hybrids have already contributed significantly in achieving highest growth rate in production and productivity of maize in the country among the food cereal crops. QPM is a solution to food and nutritional security, and baby corn and sweet corn for livelihood security in peri-urban areas. Maize is a solution for climate change, lowering water table and rising temperature in different ecologies in the country. To improve the farm profitability in maize based cropping systems crop diversification, intercropping and resource conservation technologies are most suitable. DMR/SAUs and its associated institutes are committed to bring revolution in maize production and productivity in India by formulating research strategies and their effective implementation.

References

http://www.fas.usda.gov/psdonline/

http://www.dacnet.in

Annexure I: Strategic framework

Goal	Approach	Performance Measure
Improvement of genetic yield potential	Developing productive inbred lines Use of such productive inbred lines for single cross hybrid development	High yield productive single cross hybrids
Enhancement of nutritional quality	Biochemical analysis of of lines and hybrids for various quality parameters Use of nutritionally superior lines in development of hybrids	Nutritionally improved inbred lines and hybrids
Enhancement of specialty corn profitability	Exploration and procurement of diverse germplasm lines with high genetic variability for special traits Development of QPM, popcorn and sweet corn hybrids Evaluation of early maturing single cross hybrids for yield and quality	Productive hybrids with better quality
Identification of *in-vivo* doubled haploid induction lines	Evaluation and identification of lines for high *in-vivo* doubled haploid induction	Rapid recycle of superior inbreds Suitable inducers for tropical maize

Goal	Approach	Performance Measure
	Increase inducing capacity of inbred lines Standardization of protocol for chromosome doubling and recovery of doubled genotypes	Doubled haploid inbred lines
Mitigating the effects of climate change	Precise phenotyping of germplasm lines for various abiotic and biotic stresses Breeding for various abiotic and biotic stresses through conventional, markers assisted selection and transgenic approaches	Improved parental lines and hybrids with desired traits Hybrids tolerant to various biotic and abiotic stress
Widening industrial applications	Breeding corn for high biomass, starch and its derivatives	Hybrids with high biomass and starch content
Identification of stable sources of resistance	Evaluation of inbred and hybrids under artificially inoculated condition Use of resistant lines for development of single cross hybrids	Resistant inbred lines and hybrids Reduction in cost of production Reduced yield losses Reduced inoculum load
Minimize post-harvest losses	Management of mycotoxin contamination in grains	Aflatoxin free grains

Goal	Approach	Performance Measure
Minimize yield losses due to insect pests	Evaluation for resistant sources Biorational management of stem borers through conventional methods and phytochemicals	Resistant inbred lines and hybrids Reduction in cost of production Biorational management schedule for insect pests Reduced yield losses
Identification of tolerant sources for abiotic stress	Screening/ phenotyping of maize inbred lines and hybrids tolerant to abiotic stresses	Inbred lines and hybrids tolerant to abiotic stress