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GENETIC IMPROVEMENTS IN MAIZE PRODUCTION

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ABSTRACT

Maize is the third most significant crop of nation after rice and wheat and is grown round the year. Its grain is utilized as feed, food and industrial raw material. Enormous progress has been achieved over past six decades to increase yield potential via genetic improvement and relieve impacts owing to different biotic- and abiotic-stresses. This study provides an overview of methods pursued in genetic improvement of maize and evaluates their effect on productivity and output of the crop. Development of cultivars with tolerance to abiotic-stresses and resistance to diseases has been a key issue in maize development. Improved goods have been provided to farmers by both governmental and commercial sectors engaged in maize seed manufacturing and distribution. As a consequence, area under better cultivars has been growing steadily, and now about 65 percent of maize land is under improved cultivars (mainly hybrids) (mostly hybrids). Adoption of high-yielding cultivars, better production techniques and increasing demand of maize resulted in higher output and productivity. Future possibilities of maize production and development techniques in context of climate change and in ensuring nutritional security are also addressed in this study.

KEYWORDS: *Crop, Germplasm, Genetic Improvement, Nutrition, Production.*

1. INTRODUCTION

Maize is planted in 184 million ha in 165 countries, producing 1016 million tonnes of maize worldwide and producing 5.52 tons/ha. It has become the grain which has the world's biggest output, which in 1996 exceeded rice and wheat in 1997, with production growing twice the annual pace of rice and three times the annual rate of wheat. India produces 9.0 million hectares of maize and is fourth behind the USA (35.5 million ha), China (35.3 million ha) and Brazil (15.4 million ha). Maize is the third largest rice and wheat crop in India. It uses its grain as feed, food and industrial raw materials (Figure 1). It is planted in the nation throughout the year, although most (83%) of it is grown in rain or Kharif (July - October), followed by winter or rabbit (November to April) (15%) and spring (February - May) (2%) seasons. Karnataka, Andhra Pradesh, Maharashtra, Tamil Nadu, Rajasthan, Bihar, Uttar Pradesh and Madhya Pradesh are among the major maize producing states and account for about 80 per cent of the country's total maize area and comparable output. As a food crop, maize is used more widely than other main crops, since a range of products are created from it and different kinds of maize such as quality protein maize (quality protein maize, pop maize, sweet maize, baby maize, etc.) are offered[1].

The area and maize output have increased continuously since 1950. (Figure 2). The area rose from 3.3 million to 9.0 million hectares and in 2013–2014 output grew from 1.7 million tonnes, to 24.4 million tonnes. The growth in production and extension of the area in Andhra Pradesh, Karnataka, Maharashtra and Tamil Nadu in the past 10 years has been extremely fast. The region, on the other hand, has seen a decreasing tendency in Madhya Pradesh, Uttar Pradesh, Jharkhand and Punjab in recent years. In India, maize by tradition is a kharif seasonal crop but currently grows in the rabi and spring seasons[2].

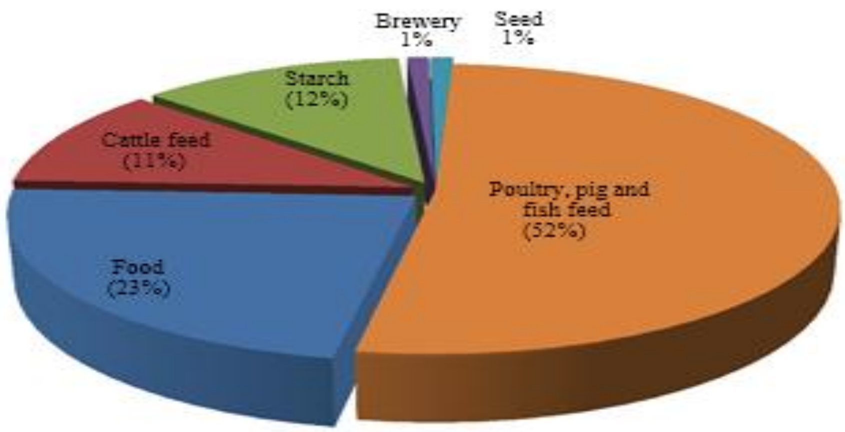

Fig. 1 Utilization pattern of maize grain in India

The production of maize in a variety of ecologies throughout the nation is susceptible to different abiotic and biotic stressors. These include high humidity and temperature, illnesses and insect pests. There have been concerted attempts to relieve the impacts of these stressors and to increase the yield potential through genetic improvement and better management. Consequently, huge progress in this area has been achieved during the last six decades. This study provides an overview of genetic enhancement methods pursued by maize in India and evaluates its effect on crop yield and output. In addition, possibilities for maize growing and improvement strategy are addressed in the context of climate change and nutritional security[3].

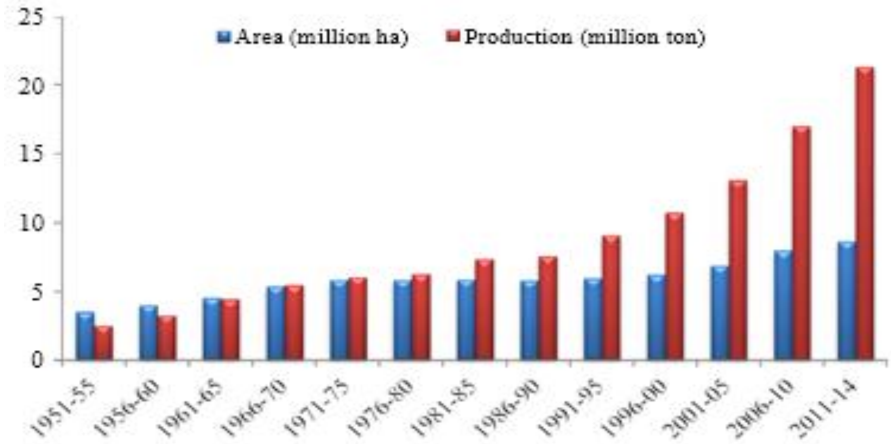

Fig. 2 Trends in area and production of maize in India since 1951

1.1 Genetic Enhancement:

1.1.1 Collection, Introduction and Use of Germplasm:

Different germplasms are a must for a successful crop enhancement programme. There have been intensive attempts to gather indigenous diversity and import alien germplasm. The studies have shown that in the Himalayan area there are land-races with primitive features called 'Sikkim Primitives' that are distinct from primitive Mexican races, e.g., Nal-Tel and Palomero. Therefore, considerable efforts have been undertaken to gather germplasm from the North East Himalayan NEH area. The Indian maize races have been categorized, based on the assessment of these and other collections, as primitive, advanced, recent introductions and hybrid races. In addition to races, many significant local variations were found, generally called according to the area in which they were mostly grown. The indigenous germplasm was big, poor yielder and mostly flint. Compared to foreign germplasm, it exhibited little diversity in Central and South America in particular. Still at that time, indigenous germplasm had a particular importance, since it developed in harmony with the prevailing agro-ecological factors and thus is anticipated to respond better to regional pressures. In the development of populations, heterotic pools and inbreds, indigenous germplasms have been utilized. The local germplasm's molecular characterization showed the varied nature of maize germplasm in India[4].

The Rockefeller Foundation also brought germplasms from various nations, notably the USA, Mexico, Colombia, Peru, Venezuela and Caribbean islands in the 1950s. Some introductions were utilized as commercial cultivars immediately. At the national genetic resources office in New Delhi, about 10,000 accessions (indigenous and exotic collections) are under long-term conservation at the National Gene Bank. Most exotic germplasms come from tropical and subtropical sources. Certain germplasms have been characterized for particular characteristics such as biotic and abiotic stressors, and nutritional quality criteria, such that over 30 sources with unique traits that are of enormous value in the breeding programme have been identified.

1.1.2 Improving The Quality of Nutrition:

The maize protein level of lysine and tryptophan is low, making it nutritionally inferior. The nutritional advantage of recessive opaque2 (o2) was discovered in India to improve the nutritional quality of maize by 2–3 times lysine and tryptophan as compared to normal maize. The discovery led to the introduction of o2 alone into an elite genetic background. These efforts resulted to the successful creation and release throughout 1971 of three o2 composites, namely Shakti, Rattan and Protina. These enhanced maize varieties were not however popular, mainly because of the chalky look and unfavorable pleiotropic effects of o2, such as soft endosperm that rendered o2 growers more susceptible to attacking stored grain insect pests. Wishful mix of endosperm modificators in the o2 backdrop. The outcome was hard endosperm-based genotyping of O2 in Mexico. In India, accumulation of CIMMYT germplasma modification in particular resulted in the introduction of Shakti-1 in 1997, the first harsh endosperm-based o2 composite. In 2001, the first QPM hybrid in India, 'Shaktiman-1' (a white three-way kernel cross), was launched and 'Shaktiman-2' (the white kernel-based SCH) was introduced in 2004. 'Shaktiman-3' and 'Shaktiman-4' were initially launched in the yellow kernel during 2006, followed by 'Shaktiman-5' in 2013. These QPM hybrids have been tailored to the state of Bihar. Later, many single-cross QPM hybrids with greater adaptation to the country's various agro ecologies have been produced.

The use of molecular markers to enhance maize in India resulted to the commercial release of the first marker aided selection (MAS) maize product (Vivek Quim-9) in 2008, combined with marker-based background selection. In 2012, a single cross QPM hybrid was published for the state of Uttarakhand from the MAS-derived Vivek QPM-21. Currently markers are used in quality breeding programmes for the faster production of QPM hybrids. The parental inbred QPM version of many commercial one-cross maize hybrids has been produced and experimental hybrids are being tested for agronomic performance assessment. Opaque16 (o16) is introduced into the o2 genetic background of a quality breeding programme to further enhance lysine and tryptophan in endosperm. The mutant o2 and o16 combinations provide a 40–80 percent improvement in lysine compared to just o2o2 genotypes[5].

The enhancement of maize vitamin A is a new emphasis in India. While conventional yellow maize has enormous natural diversity in carotenoids, lutein and zeaxanthine, which have little provitaminA action, are mostly carotenoids. The main carotenoid pro-vitamin A is b-carotene at minute concentrations. Multi-location assessment of a wide range of yellow corn infusions showed a 0.1–2.0 ppm level of b-carotene below the desired level of 15 ppm in the maize kernel. A unique b-carotene hydroxylase alone (crtRB1) which enhances b-carotene by preventing its conversion to other components was incorporated into seven elite inbred parents with MAS. The reconstituted hybrid form exhibited a huge increase in the b-carotene kernel with a mean of 17.5 ppm, whereas the original hybrids were 2.1 ppm. Research initiatives have also been started in India to produce multi-nutrient rich maize. A QPM hybrid form of provitamin-A-rich is presently being tested in multi-location locations. In addition, in conjunction with CrtRB1, uncommon allele lycopene epsilone cyclase (lcyE), which pushes the lycopene flow toward b-carotene, is also used for additional enrichment of b-carotene in the genetic background of commercially available QPM hybrids[6].

Research has also been started in India on the creation of maize with high iron (Fe) and zinc (Zn) mineral density. Analyzes of large sets of indigenous and foreign maize inbreds showed significant potential to increase Fe and Zn levels via breeding. Identifying QPM inbreds with high Fe and Zn also offers further advantages in the use of endosperm for high lysine and tryptophan. Zn-transporters' genome-wide analyses may identify some important genes responsible for Zn build-up in maize kernel. In addition, a marker-assisted introduction of low-phytate mutants into top normal inbreds of maize has been conducted to improve the bioavailability of Fe and Zn. The findings are promising since these MAS-derived lines are suitably low in phytate.

1.2 Corn Specialty:

In recent years, demand for specialized maize has risen by several folds. Sweet maize has evolved among many varieties as one of the most significant types of speciality maize, utilized mostly as fresh, processed vegetables and snacks. The first composite of sweet maize called 'Madhuri' was launched in 1990. Additional attempts to create various sweet maize cultivars resulted to the development of several additional sweet maize cultivars such as Priya, Win Orange and HSC 1. Sweet maize hybrids are currently being developed in the genetic field of sucary1 (su1) or shrink 2 (sh2). Identification of closely related SSR markers for su1 and sh2 has also given the elite genetic background a new dimension to the marker aided introgression of these genes.

Popcorn and baby corn are also cultivated, especially in the peri-urban region. In 2004 the first infant variety, VL-78, was launched. The public sector groups have also released a few pop maize collages. Quantitative characteristics loci (QTL) have been discovered for several appearance characteristics in maize, giving a possibility to integrate them into the elite flint genetic field via MAS.

Starch was one of the major by-products of maize grain and 12% of the maize produced now is utilized in the starch industry. A three-way, starch-rich hybrid 'Histarch Hybrid Makka' was launched in 1993. HM-13 just launched a SCH with increased starch content in grain. In addition, several waxy maize inbreds were also produced and utilized in the breeding effort. Genetically, many inbreds of high oil have been created and are significant in the variety development, since in chicken business high oil feed is desired.

Efforts to improve maize crops for fodder production to address the requirement for the mixed crop farming system resulted in the distribution of African Tall green feed to the whole nation in 1982. Composite APFM-8 was introduced in 1997 to cultivate in the country's southern area. In 1992 and 2008 respectively, J-1006 (for Punjab) and PratapMakka Chari 6 were published. The further popularization of sweet maize and baby maize varieties also gives the agricultural system a new dimension since they offer adequate feed after the ear harvest.

1.3 Improving Disease and Resistance to Insects:

Although there have been over 30 cases of illness recorded in various Indian areas, significant diseases include turquoise leaf blight, maydis leaf blight, complicated post-flowing stalks, leaf banding and sheath blight, sorghum downy mildew, bacterial stalk red and brown strip downy mildew. These diseases occur depending on the prevailing environment (temperature, precipitation and wetland), cultural practices (planting density) and maize crop variety in various agro-ecological areas. Such illnesses cause huge losses in both the amount and quality of grain produced under favorable circumstances. Resistance breeding of host plants has been focused, because resistance to host plants is sustainable and cost-effective. Following a thorough knowledge of the epidemiology of many diseases, field checking methods were developed, capable of distinguishing resistant and susceptible lines and utilized widely in breeding programmes for resistance. Cultural and chemical methods were also developed to manage these diseases, in addition to the use of host plant resistance. However, chemical control methods are mainly limited to plots of seed production and to commercial hybrid seed treatment supplied to farmers[7].

Three insects - stem borer, pink stem borer and shooting fly - in India are the major problems. These are usually managed by the use of pesticides. In addition, germplasms under artificial infestation are continually assessed to discover resistant sources of these insect pests. Antigua Group 1 has attracted attention as a resistant source for a long time. It was also utilized as a hybrid ganga male parent (CM 500). Recent attempts via cyclic selection and artificial inbreeding in order to enhance moderately resistant sources have been fairly successful in minimizing leaf damage. Resistance to pink borer is also observed in inbreds. Maize grains are also infected by a broad variety of storage insect pests that have resulted as voracious feeders of cereal grains, including rice weevil and Angoumois grain moth. Grains are typically kept in jute bags in poor nations such as India that frequently absorb humidity during the rainy season and provide favorable circumstances for weevil infestations. A large screening of several inbreds, including QPM, pop maize and candy maize has led to the discovery of rice weevil-resistant sources. These sources of resistance are promising their objective use in the breeding programme. Furthermore, in recent years, biological control via Trichogrammachilonis has gained importance. Integrated pest management approach may also offer ways to control insect pests in a sustainable manner[8].

1.4 Improving The Tolerance of Abiotic Stress:

Maize is mainly cultivated (over 80 percent) during rainy season and the availability of moisture is seldom sufficient for maize of Kharif. The crop is also susceptible to dependent / intermittent excessive moisture / water recovery or drought at key development phases, often within the same season. Rabi maize acreage is frequently limited (15 percent) by protracted low-temperature regimes in most areas of India, with the exception of South India, in December and January. In crucial periods of development, particularly during early planting and blooming phases, cold stress may induce permanent physiological damage to maize plants, leading to significant production losses[9].

The impact of climate change, which is plainly shown by the increasing frequency of severe weather, presents additional difficulties for an already sub-optimal/challenging environment. Several climate modelling studies have shown a faster rise in daytime and night time, intense and concentrated rainfall within restricted days, which causes shorter-term water logging and leaves severe dry days in the Asian tropics for the remainder of the season. This is evident in a recent Indian Meteorological Department study based on previous 110 years, which showed that while the overall rainfall has not changed much in recent years, the frequency of wet days has dropped dramatically and this has resulted in the high availability of humidity. In various areas of maize production, such changes are already seen in many ways, in terms of changing seasons and increased rates of severe weather events, such as drought, water collecting and heat combined with new/complex diseases[10].

2. DISCUSSION

A well-organized seed production programme is vital in order to fully exploit the benefits of enhanced hybrid cultivars. Compared to hybrids and composites, inbred lines need a distinct package of production technologies, such as crop geometry and the reduction in fertilizer and water management. Previously, inbred parents' agronomy did not get much attention. During these last two decades the agronomy of inbred lines has received appropriate attention, as well as the creation of high-yielding inbred lines have made excellent progress. In addition, the modernization of seed processing and packaging has improved significantly.

Both the governmental and commercial sectors participate in the manufacturing and distribution of maize seeds. In addition to generating certified hybrid seed, the public sector provides the breeder and founding seed of parental hybrid lines to the private sector. The seed production activities are being conducted by the NSC, 15 State Seed Corporations (SSC), several State Departments of Agriculture and Agricultural Universities. Recently in Rajasthan and West Bengal, a seed village idea was established to grow certified seed in accordance with specific arrangements of government to enhance food safety and nutrition. The private sector, like always, has a significant stake in the seed business. Due to favorable growing conditions and sufficient seed processing facilities, the majority of seed production is carried out during the rabi season in Andhra Pradesh.

Public sector entities undertake hybrid seed manufacturing and sale of public-sector maize hybrids, but enough seed is not produced to satisfy demand. Therefore, public-private partnership (PPPs) has been formed between public-sector research institutes and small and medium-sized private seed businesses for development and commercialization of public-species hybrids. This is of tremendous assistance in prompt distribution and replacement of newly released cultivars. Another example of PPP is the assessment of hybrids in the private sector by coordinated project centers throughout India. Under addition to the existing tests of private-section hybrids in the All India Coordinated Research Project (AICRP) method and the seed production outsourcing and marketing by the private sector of public-species hybrids, the PPP model must nevertheless be strengthened. In the context of successful PPP models such as Germplasm Enhancement of Maize (GEM) in the United States and TAMNET in Asia, future partnerships must collaboratively increase the germplasm of different goals in order to promote the creation of better germplasm.

3. CONCLUSION

In future, demand for maize is projected to increase. The key drivers of maize demand in India are (a) increased demand by the poultry and piggy sector, consuming more than half of domestic production, (b) growing urbanization leading to increased demand for processed foodstuffs, such as corn flakes, bakers, etc., (c) increasing organized dairy sector, requiring more fine cereals and more concentrate from the maize sector and (d) increasing domestic prices. The anticipated development of feed-based industries suggests that maize consumption would increase in India from the present level of 25 million tonnes, to 45 million tonnes, by 2030. India should be able to achieve more than this goal by expanding the genetic improvement programme and by developing adequate agro-interventions and appropriate regulations.

Germplasm base diversification Only by constant infusion of more and more varied elite germplasm from temperate areas can the continual increase in production be accomplished. Only a portion of the broad genetic diversity in maize has been used thus far. Without disrupting heterotic groups, recycling current elite lines may further improve output in the near run. However, extending the germplasm base to include characteristics such as drought and water tolerance, diseases and insect resistance, superior nutritional qualities, good standing and the required characteristics for climate resilience are particularly useful in order to sustain long-term genetic productivity and stability gains. To date, little emphasis has been paid to the exploitation of temperate germplasm. Temperate material is a potential source of hybrid-oriented germplasm diversity. The genetic basis for speciality maize and forage maize germplasm, accessible from Indian maize farmers, has to be extended quickly.

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