5. MAIZE PRODUCTION CONDITIONS IN INDIA AND FUTURE PROBLEMS

D. SHARMA

Economic Botanist with Millet and Maize, Punjab Agriculture University
Ludhiana, India

Maize is an important cereal crop in India and in certain parts like foot hills of the Himalayas, it forms the staple diet of the people in the winter months. At present 98 per cent of the total maize production in the country is used for human consumption. As India is well known for its diversity in every walk of life, the area of 11.5 million acres sown under maize also represents diverse conditions of soil type, rainfall and temperature. The crop is grown on rich clay to sandy loam soils in areas with temperature and rainfall ranges of 10°C to 37°C and 20″ to 110″ or more respectively.

To meet the specific requirements of maize varieties suitable for different conditions the maize growing area in the country has been divided into four agro-climatic zones as shown in Fig. 1.

1. Zone I — It constitutes of Himalayan foot hills having an altitude of 3000′ to 7000′ and rainfall 25″ to 100″.
2. Zone II — Northern plains having an average rainfall 20″ to 30″.
3. Zone III — Northern plains in the foot of mountains having humid condition with rainfall of 30″ to 50″.
4. Zone IV — Peninsular India having dry low rainfall conditions.

It may be emphasized here that in India there is nothing like a corn belt as in U.S.A. in which a large maize growing area has highly favourable climate for maize growing. Therefore, we are not in happy situation where one or two varieties may serve the needs of the entire area, as in the case in Thailand where only one variety predominates in most of the maize area. Breeders in India are faced with the problem of developing a large number of varieties suitable for the specific growing conditions obtaining in the different regions. Also within the zones the agro-climatic conditions are highly diverse. Under such diverse climatic conditions Wellhausen indicated the need of about 250 varieties in Mexico. Similarly in case of India either we may have to develop 200 to 300 varieties or fewer number of varieties having very wide adaptability.

Introduction of maize in India dates back to the early 17th century by the Portuguese settlers on the West Coast of India. It continued to be grown as a rarity or delicacy in small areas, but with the increasing population, development and synthesis of different cultures, it soon spread out as cultivated plant. The original form of maize introduced in our country appears to be pop flint with orange yellow grain characteristics and through centuries of association with this form, natural geographical barriers of sea and mountains, continual process of inbreeding (in the absence of integration of any exotic germplasm), it remained just a form with low yield and narrow gene base.

Fig. 1. Maize Research Centres of India.

ZONE	NAME OF THE CENTERS
Zone I	Srinagar, Almora, Bajaura, Kalimpong, Solan and Gangtok.
Zone II	IARI, New Delhi, Ajmer and Ludhiana.
Zone III	UPAU, Pantnagar and Dholi.
Zone IV	Hyderabad, Chhindwara, Godhra and Arbhavi.

The yield level of local varieties is 1,250 kg/ha. These varieties lack heterotic response in hybrid combinations among themselves. The superior germplasm of Indian varieties is represented by the following—

1.	HM-1	Orange yellow flint type of Andhra Pradesh, South India.
2.	Bassi	Orange yellow flint type from Rajasthan, Central India.
3.	Malan White	White flint from Rajasthan, Central India.
4.	Rudrapur Local	White flint from U.P., Northern India.
5.	Jawanpur White	White flint from North Bihar.
6.	Solan Local	Deep orange yellow flint from hilly areas in the Himachal Pradesh.

The local varieties are early maturing with 80 to 90 days of maturity.

With the initiation of the All-India Coordinated Maize Improvement Program in 1957 in collaboration with The Rockefeller Foundation, rapid progress was made in the development and release of hybrid varieties for cultivation and seven high yielding hybrids possessing desirable maturity, flint to semi-flint grain type and resistance to major diseases. The different hybrids under cultivation are given in Table 1 with the regions for which recommended and their yield level.

In general the yield levels of the hybrids over five years of testing are 4,500 to 6,500 kg/ha in plains and sometime yield of as much as 9,000 kg/ha is obtained in the hilly areas where climate is highly conducive for maize production.

In 1961–62 the area sown under hybrid maize was only 780 acres, but in 1967 the National Seeds Corporation produced enough hybrid maize seed to cover 2.3 million acres (about 20% of the total maize area). Nevertheless, there is a feeling among the maize workers of India that the coverage under high yielding varieties of maize had been rather slow and therefore, there was a need for looking an alternative breeding procedure by which it should be possible to develop varieties for large scale coverage within a short period and limited technical and financial resources.

The investigations under the All-India Coordinated Maize Improvement Program have shown that certain combinations of inter-racial crosses are capable of giving as high yields as of the hybrids and have other desirable attributes as the best hybrids at present under cultivation. The performance of advance generations of such combinations have demonstrated that their yield potential does not decrease significantly. Genetic analysis of yield and other quantitative traits in such composite populations have revealed that additive gene action predominates and therefore, it is quite possible to accumulate desirable favourable genes through appropriate selection schemes in a short period and to have a progressive increase in maize yield till it reaches a plateau, while in case of hybrids the yield level remains fixed.

Therefore, at present, the main emphasis in the maize breeding program in India is being laid on the breeding and development of the composite varieties, and out of more than 250 races of maize present in Latin America five outstanding germplams viz., Tuxpeno from Mexico, Cuban Flint from Cuba, Coastal Tropical Flint from the Caribbean region, Salvadoreno from Central America and Eto from Columbia are being extensively used for the development of high yielding and disease resistant composite varieties. In May, 1967 six outstanding composite varieties were released for cultivation. The Table 1 gives the yield levels and region of adaptation for these varieties. The composites have a wider range of adaptation than the hybrids, and it has been easier to incorporate in them both polygenic and major gene resistance to the diseases. In 1967 for the first time sufficient seed was produced to cover about 0.25 million acres under these varieties. With the introduction of these varieties it should not be difficult to cover at least 50 per cent of the total maize area under high yielding maize

Table 1. Yield potential of the hybrids and the composites and the recommended regions.

Sl. No.	Name of Hybrids/ Composites	Area for which suited	Duration in days	Yield potential (kg/ha)
	HYBRIDS			
1.	Ganga-101	Northern Plains	100—110	4,000—5,000
2.	Ranjit	South Rajasthan, Gujrat and Maharastra	100—110	4,500—5,600
3.	Deccan	Peninsular India	105—115	5,000—6,000
4.	Ganga Safed-2	U.P., Bihar, West Bengal and Rajasthan	95—100	4,500—5,300
5.	Hi-starch	All maize area	95—110	5,500—6,700
6.	Ganga-3	Northern Plains	90— 95	4,500—5,500
7.	Himalayan-123	Himalayan Hills	105—115	5,500—8,000*
	COMPOSITES			
1.	Ambra	Northern hilly areas and Peninsular India	110—115	6,500—7,800*
2.	Jawahar	Northern plains and Peninsular India	100—110	4,500—5,500
3.	Kissan	Northern Plains	105—110	4,500—5,500
4.	Vikram	Northern Plains	90—100	4,000—5,000
5.	Sona	Northern Plains	90—100	4,500—5,000
6.	Vijay	Northern Plains and Himalayan Hills	100—105	5,500—8,000*

* The figures marked with asterisk are from the hilly areas of Himalayas.

varieties by 1969, which would increase the maize production in the country by many folds and soon it may be possible to divert this increased production to the various industrial uses of maize.

Agronomic and Cultural Practices

There are two crop seasons in India. The plantings for the monsoon crop start from May in certain hilly areas and mid-June in plains and the harvesting is done from September to October. In Peninsular India, a considerable area under maize is planted during November and harvested from March to April. Most of the area under May and June plantings is rainfed while the area under November sowings is irrigated.

The open pollinated varieties of maize are planted at very high plant population rate, generally by broad-cast method or by drilling behind a wooden plough. The experiments done with the hybrid varieties of maize have shown that the best yields are obtained at 50 thousand plant population per hectare and 150 kg N/ha.

Also the results of experiments conducted on dates of planting have shown that maize plantings done earlier than the usual planting with the onset of the monsoon offers more favourable conditions of growth and results in higher grain yield at almost all the locations except where the irrigation facilities are lacking.

The experiments on fertilizers other than nitrogenous fertilizers show that most of the farmers fields are low in phosphorus or potash and an application of these nutrients to maize can increase the yield phenomenally and can bring highly profitable returns. Generally an application of 32 kgs of P_2O_5/acre and 30 kgs of K/acre is recommended.

In recent years with the introduction of high yielding dwarf wheat varieties the farmers have started applying high doses of phosphatic fertilizer to the wheat crop and therefore, it is being experienced that maize yields may be limited by micronutrient deficiency particularly of zinc. The trials conducted have shown that an application of 10 kgs of commercial zinc-sulphate may be very useful in getting good yield of maize.

Diseases and Insect Pests

Since maize in India is grown under all sort of climatic conditions, almost all the diseases of maize are found to some extent. However, the following seems to be quite important—

1.	Leaf blight	a) *Helminthosporium turcicum*
		b) *Helminthosporium maydis*
2.	Leaf strip disease	*Xanthomonas rubrilineans*
3.	New downy mildew	*Sclerophthora rayssiae*
4.	Cephalosporium stalk rot and ear rots	
5.	Stalk rots caused by Phythium, Ervinia Carotovora and diplodia	
6.	Brown spot	*Physoderma maydis*
7.	Downy mildew	*S. philippinansis.*

Presidently, work is in progress to screen the maize germplasm for the major diseases and efforts are being made to incorporate the resistence from the known sources. In case of northern leaf blight attempts are being made to utilize single gene dominant resistance as well as polygenic resistance. Accumulation of genes through simple recurrent selection for resistance to cephalosporium stalk rot is being carried in three composites viz. A_1 × Antigua Gr. I, J_1 × Cuba 11J and J_1 × Coastal Tropical Flints. In total, 1271 S_1 lines have been established for resistance which are being tested further.

Also the tests have shown that the inbred line CM-104 was resistant to infections with *Xanthomonas rubrilineans* and the hybrid Hi-starch had resistance for cephalosporium stalk rot. Also a recent released hybrid Ganga-5 is highly resistant to *Xanthomonas rubrilineans* as compared to the hybrid Ganga-3 which is highly susceptible to the disease.

Insects

Maize borer (*Chilo zonellus*) is the only insect which causes appreciable damage to the maize crop. The studies carried out on the evaluation of damage in maize by *C. zonellus* indicated that two applications of endrin saved a loss of 13.7 quintals per hectare over the control inspite of the fact that the treatment could not reduce the percentage infestation to the zero level. The studies also revealed that late sown crop was less infested and less tunneled as compared to the early sown crop.

The screening tests for resistance to *C. zonellus* showed that the composites A_1 × Antigua Gr. I, Barbi dose Gr. I, Caribbean Flint composite and Cuba 11J formed the least susceptible group, while Sonora Gr. II and A_4 composite were the most susceptible. Work on selective breeding for resistance to *C. zonellus* is in progress.

Future Problems of Maize Breeding

Maize is generally followed by wheat or potato crop and therefore, the farmers have a preference for early maturing maize varieties (80 to 85 days maturity). The maize hybrids are in the range of 95 to 110 days maturity though the mechanization of farm operations has removed this objection to some extent but still there is a demand of early maturing types. Presently some U.S. Argentine and Japanese maize germplasms are being utilized to develop suitable early maturing varieties. Recently cross, Antigua Gr. II × Narusawa in F_3 generation involving the Japanese variety Narusawa has been found quite promising.

In certain parts of the country high rainfall and high wind velocity causes considerable damage through lodging of the crop. To overcome it the work has already been initiated for the development of compact dwarf type. This is being done by incorporation of brachytic-2 gene in the inbred lines as well as in broad gene base composites. The preliminary indications are that the latter may prove more useful since in case of composite background there is a whole range of compacts and dwarfs due to the effect of modifiers in different genotypes and hence it becomes possible to select for the desirable height with good ear size.

Adequate seed production of hybrid varieties at minimum expenditure has always posed a problem in the country and it is increasing with the increasing demand for the seed. To overcome this, major emphasis is being now laid on the development and production of composite varieties. Also the problem is being tackled by the development of double top crosses which involve a single cross and a variety as parents and by investigating the possibility of developing early generation limited inbred hybrids.

Large acreage of maize in the country is grown under rainfed conditions and therefore, there is need for drought resistance in the maize varieties, so that in the areas where rainfall is not well distributed there may not be complete failure of the crop. The hybrid Ganga Safed-2 has been found to stand the moisture stress conditions better.

As I indicated that 98 per cent of the total maize production in the country is utilized for human consumption, therefore, there is a great urgency for more nutritive and balanced protein in maize. The o_2 and fl_2 genes are being incorporated in inbred lines of released hybrids and composites. Data from Purdue University indicates that o_2 and fl_2 genes double the quantity of the essential amino acids, lysine and methionine respectively.

In future the main problem in the way of keeping a very high level of maize production in the country through sizeable area and improved cultural practices, would be the market price of the grain. If pace is not kept in finding and establishing alternative use of the produce in the industrial products, it would be difficult to maintain remunerative market price of maize. With the increased industrial use the breeding work will have to be geared up to meet the specific demand of the industry, such as varieties for high starch and probably with high amylose content.

Discussion

K. Murakami, Japan: In your country, composite varieties are named composite A_1, A_2, B_1, B_2, etc. Are the composite varieties Ambar, Jawahar, etc. you stated different from composite A_1, A_2, B_1, B_2, etc.?

Answer: The names you have mentioned are the names for the varieties in the breeders record and are after the code letter assigned to a research station. While the name of the released composites are the given popular names.

N. Mochizuki, Japan: 1. Have the composites in India been developed from inbred lines or open-pollinated varieties? 2. What is the purpose of developing composite? Is it for directly farmer's use or long term selection project? 3. Do you use term "composite" and "synthetic variety" interchangeably?

Answer: 1. From open-pollinated varieties. 2. For direct release and simultaneous continuous improvement through appropriate selection procedures. 3. No. Composites are the varieties developed from open-pollinated varieties. Synthetics are developed from inbred lines.