IARI BEST PRACTICE

1. Title of the practice

DEVELOPMENT OF BIOFORTIFIED MAIZE HYBRIDS FOR FOOD- AND NUTRITIONAL- SECURITY

2. Objectives of the practice

Maize is one of important cereal crops of the country. It is the rich source of carbohydrate in the diet. However, maize is deficient in lysine (1.5-2.0%), tryptophan (0.3-0.4%) and provitamin-A (1.0-2.0 ppm) that causes health problems such as protein energy malnutrition (PEM) and vitamin A deficiency (VAD). The objective of the research work is to develop biofortified maize hybrids rich in protein quality (lysine & tryptophan) and provitamin-A (proA) through breeding. The landmark discovery of *opaque2* (*o2*) gene for increasing lysine & tryptophan; *β-carotene hydroxylase* (*crtRB1*) and *lycopene epsilon cyclase* (*lcyE*) for increasing proA has promised for maize biofortification. The strategy of marker-assisted selection (MAS) for selection/ introgression of these major genes was employed to develop biofortified maize varieties in accelerated manner.

3. The context

Micronutrient malnutrition is the serious health issue that has impacted two billion people worldwide. In India, 15.3% of the population are undernourished with high child mortality rate. India loses over US$12 billion in GDP per year to vitamin and mineral deficiencies. Also. India ranks 101 among 116 countries with respect to global hunger index. Maize or corn is one of the important cereal crop that provides significant amount of calories in the daily diet. However, it is deficient in essential amino acids, micronutrients and vitamins. It is, therefore, very essential to increase the amount of nutrients in maize endosperm to alleviate malnutrition especially among the population dependent on maize as staple crop. Biofortification is the process of developing nutrient-rich crops through breeding approaches, which provides sustainable and cost-effective solution compared to 'food-fortification', 'dietary diversification' and 'medical-supplementation' to address malnutrition. Considering this, the development of biofortified maize hybrids with high grain yield potential and enriched amount of vitamins and protein quality is one of the the most important objectives of maize improvement.

4. The practice

In India, Shakti, Rattan and Protina, the *o2*-based soft endosperm maize composites were released during 1971 by All India Coordinated Research Project (AICRP) on Maize, and these are perhaps the first set of biofortified varieties developed through targeted breeding approaches across crops in the country. Later, a series of QPM hybrids were developed using conventional breeding. The cloning and characterization of the *O2* gene, followed by detection of gene specific three SSRs *viz*., *phi057*, *phi112* and *umc1066*, offers advantages in marker-assisted selection for rapid development of QPM hybrids. In India, a MAS-derived

QPM hybrid, ‘Vivek QPM 9’, was released during 2008 by the ICAR-Vivekananda Parvatiya Krishi Anusandhan Sansthan (VPKAS), Almora. Research efforts at ICAR-Indian Agricultural Research Institute (IARI), New Delhi have led the development of three QPM hybrids viz., Pusa HM-4 Improved, Pusa HM-8 Improved, and Pusa HM-9 Improved released for commercial cultivation during 2017 by Central Variety Release Committee (CVRC). Subsequently, IARI has developed series of QPM hybrids enriched with provitamin A, thus multinutrient maize hybrids.

To develop proA rich hybrids, large scale validation of the effects of molecular marker polymorphisms in *lcyE* and *crtRB1* was carried out at CIMMYT, employing MAS. At IARI, breeders have introgressed the favourable allele of *crtRB1* gene from CIMMYT-HarvestPlus genotypes to Indian adapted genotypes and developed proA rich normal as well as QPM hybrids. These biofortified hybrids are adapted to diverse ecological regions of India. The proA version of Vivek QPM9 named as ‘Pusa Vivek QPM9 improved’ has been released for commercial cultivation in India by Central Variety Release Committee during year 2017. ‘Pusa Vivek QPM 9 Improved’ is the world’s first multinutrient-rich maize genotype, combining high quality protein with provitamin-A. This is unique hybrid successfully developed by IARI, New Delhi in the country.

5. Evidence of success

IARI has successfully developed nine biofortified hybrids comprising of 3 QPM hybrids, 1 proA rich hybrid and 5 QPM + proA hybrids. Eight hybrids are the improved versions of original hybrids, and hence called as ‘Essentially derived varieties (EDVs)’ while one hybrid is independently developed by IARI. These 9 are released notified for commercial cultivation across the different zones of country. All the QPM hybrids possessed high lysine (>2.5%) and tryptophan (>0.7%) compared to lysine (1.5-2.0%) and tryptophan (0.3-0.4%) in normal maize hybrids. Similarly, proA rich hybrids possessed proA (>5.0 ppm) compared to proA (1.0-2.0 ppm) in normal maize hybrids. The details of biofortified hybrids have been provided in table 1. These biofortified hybrids have been released for commercial cultivation after its successful testing under AICRP centres. The grain yield performance of EDVs was *at par* with original/check hybrid, while the performance of independent hybrid, Pusa Biofortified Maize Hybrid-1 was superior over the checks during AICRP testing for the three years. These IARI developed varieties can potentially provide sustainable solution to alleviate micronutrient deficiency such as protein energy malnutrition and vitamin A deficiency.

Table 1: List of biofortified maize hybrids released and notified from IARI, New Delhi

SL. No.	Hybrids Name	Recommended for area of cultivation	Grain yield (q/ha)	Reference	Season	Improved trait
1.	Pusa HM-4 Improved (AQH-4)	Punjab, Haryana, Delhi, Uttarakhand and Uttar Pradesh.	64.2	The Gazette of India No. S.O. 2805(E) dated 25th August, 2017. MoA & FW, Govt. Of India	Kharif Season	Quality protein maize

2.	Pusa HM-8 Improved (AQH-8)	Maharashtra, Karnataka, Andhra Pradesh, Telangana, Tamil Nadu	62.6	The Gazette of India No. S.O. 2805(E) dated 25th August, 2017. MoA & FW, Govt. Of India	Kharif Season	Quality protein maize
3.	Pusa HM-9 Improved (AQH-9)	Bihar, Jharkhand, Odissa, Uttar Pradesh and West Bengal	52.0	The Gazette of India No. S.O. 2805(E) dated 25th August, 2017. MoA & FW, Govt. Of India	Kharif Season	Quality protein maize
4.	Pusa Vivek QPM-9 Improved (APQH-9)	Jammu and Kashmir, Himachal Pradesh, Uttarakhand, Meghalaya, Sikkim, Assam, Tripura, Nagaland, Manipur, Arunachal Pradesh, Maharashtra, Andhra Pradesh, Tamil Nadu and Telangana	Northern Hills Zone: 55.9 & Peninsular Zone: 59.2	The Gazette of India No. S.O. 2805(E) dated 25th August, 2017. MoA & FW, Govt. Of India	Kharif Season	Provitamin A and Quality protein maize
5.	Pusa HQPM-5 Improved (APQH5)	Jammu and Kashmir, Himachal Pradesh, Uttarakhand (Hill region), Meghalaya, Sikkim, Assam, Tripura, Nagaland, Manipur, Arunachal Pradesh, Punjab, Haryana, Delhi, Uttarakhand, (Plain), Uttar Pradesh (Western region), Bihar, Jharkhand, Odisha, Uttar Pradesh,, West Bengal, Maharashtra, Karnataka, Andhra Pradesh, Telangana, Tamil Nadu Gujarat, Madhya Pradesh, Chhattisgarh, Rajasthan	Northern Hills Zone: 72.6, North Western Plain Zone: 75.1, North Eastern Plain Zone: 75.1, Peninsular Zone: 59.2, Central West Zone: 51.2	The Gazette of India No. S.O. 99(E) dated 6th January 2020. MoA & FW, Govt. Of India	Kharif Season	Biofortified maize rich in Provitamin A and quality protein
6.	Pusa Vivek Hybrid-27 Improved (APH27)	Bihar, Jharkhand, Odisha, Uttar Pradesh (Eastern region), West Bengal	48.5	The Gazette of India No. S.O. 99(E) dated 6th January 2020. MoA & FW, Govt. Of India	Kharif Season	Biofortified maize rich in Provitamin A
7.	Pusa HQPM-7 Improved (APQH7)	Maharashtra, Karnataka, Andhra Pradesh, Telangana, Tamil Nadu	74.5	The Gazette of India No. S.O. 99(E) dated 6th January 2020. MoA & FW, Govt. Of India	Kharif Season	Biofortified maize rich in Provitamin A and quality protein
8.	Pusa HQPM-1 Improved	Jammu and Kashmir, Himachal Pradesh, Uttarakhand, (Hill region) Meghalaya, Sikkim, Assam, Tripura, Nagaland, Manipur, Arunachal Pradesh; Punjab, Haryana, Delhi, Uttarakhand (Plain), Uttar Pradesh (Western region); Bihar, Jharkhand, Odisha, Uttar Pradesh (Eastern region), West Bengal; Maharashtra, Karnataka, Andhra Pradesh, Telangana, Tamil Nadu and Gujarat, Madhya Pradesh, Chhattisgarh and Rajasthan	Northern Hills Zone: 81.9, North Western Plain Zone: 69.7, North Eastern Plain Zone: 59.5, Peninsular Zone: 79.3, Central West Zone: 50.9	The Gazette of India No. S.O. 8(E) dated 3th January 2022. MoA & FW, Govt. Of India	Kharif Season	Biofortified maize rich in Provitamin A and quality protein

9.	Pusa Biofortified Maize Hybrid-1	Union territory of Jammu and Kashmir, Himachal Pradesh, Uttarakhand, (Hill region) Meghalaya, Sikkim, Assam, Tripura, Nagaland, Manipur, Arunachal Pradesh, Bihar, Jharkhand, Odisha, Uttar Pradesh (Eastern region), West Bengal	Northern Hills Zone: 76.2, North Eastern Plain Zone: 54.4,	The Gazette of India No. S.O. 8(E) dated 3th January 2022. MoA & FW, Govt. Of India	Kharif Season	Biofortified maize rich in Provitamin A and quality protein

6. Problems encountered and Resources required

The recent advances in plant biotechnology including discovery of molecular markers have accelerated introgression of the target gene(s), in high yielding varieties/lines. Conventional breeding approach to develop QPM genotypes is tedious and time consuming. Consequently, introgression of *o2* through conventional backcrossing becomes demanding due to several reasons *viz*., (i) inability to identify *o2* recessive allele in each backcross generations, (ii) requirement of about six generations of backcrossing to recover satisfactory levels of recurrent parent genome, and (iii) cumbersome biochemical tests of lysine and tryptophan levels in the selected materials in each generation. These steps require enormous labour, time, and material resources. Marker-assisted backcross breeding (MABB), on the contrary, offers tremendous potential to improve the efficiency and accuracy of selection.

Biofortified crops possess great potential to provide food and nutritional security. However, the area under biofortified crops is too small to amount compared to traditional varieties. There are several challenges for adoption and popularization of biofortified maize. There is need to widen the genetic base of biofortified maize germplasm for the development of more diverse hybrids adaptable to various agro-ecologies. The biofortified germplasm should also possess adequate tolerance to major biotic and abiotic stresses to sustain high grain yield. Extensive demonstration of improved biofortified maize technologies in the farmers' field need to be undertaken by conducting large scale on-farm demonstration. Quality seed production is the major issue for meeting the seed demand of biofortified maize. Participatory seed production programme including various stake holders needs to be developed for assuring quality seed availability. Awareness generation on importance of biofortified food crops is also an important aspect of commercialization. It has now been well established that the biofortified varieties are *at par* with non-biofortified varieties for their yield potential, therefore yield inferiority should not be cause for non-adoption of biofortified varieties. The benefit of biofortified maize on human health has been well documented. Extension agencies should reach to the villagers for higher adoption of biofortified maize hybrids. Nutritious food is an important factor to the infants and young children for alleviating malnutrition. Family heads and especially mothers are the key to the adoption of biofortified maize as food in the family. Animal sector is also required to be sensitized on advantages of biofortified maize on poultry birds and pigs, and its subsequent net returns. Linkages with the poultry sector should be strengthened. Policy intervention is also necessary for the popularization of biofortified crops. The adoption of biofortified maize may be enhanced by supporting poultry and maize based processed food industries through subsidies and loans. There is also a need of attaching premium price to biofortified grains over available traditional maize. The protocol for segregation of biofortified maize grains from normal corn in the markets needs to be standardized. Inclusion of biofortified foods in different government sponsored schemes related to child and maternal nutrition would further help in alleviating the malnutrition.