Best Practices of Maize Production Technologies in South Asia

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Foreword

Maize is the one of the important food crops in the world and it provides 33.3% and 66.6% nutrition for human beings and animals, respectively. Maize serves as basic raw material for the production of food, feed, fodder and fuel. Maize recognized as one of the highest producing cereal crop in the world and rapidly emerging as a key crop in Asian food systems. 70% of the maize harvest in Asia feeds the prodigious growth of the livestock sector, showing that maize is central to growing prosperity and changing lifestyles in the continent. Currently, South Asia is facing new but equally daunting challenges. By 2050, the United Nations predicts the world's population will grow by more than two billion people, 30% of which will be in South and Southeast Asia. These regions are also where the effects of climate change, like variable rainfall and extreme flooding, are most dire. According to recent studies by CIMMYT, Wheat, maize and rice yields in South Asia could decrease by as much as 30% over this century unless farmers adopt innovations to mitigate rising temperatures and changing rainfall patterns.

Considering the significant role in livelihood of maize crops in South Asia it is important to adopt a proven technology and exchange the innovative technologies among the South Asian Countries. SAARC Agriculture Centre in collaboration with International Maize and Wheat Improvement Centre (CIMMYT)-Bangladesh, organized a Regional Video Conference Meeting on "Proven Technology sharing of Maize in SAARC Countries" on 18 September 2017 at SAARC Agriculture Centre, Dhaka, Bangladesh. To generate interactions and exchange of knowledge and proven technological information, experts from SAARC Member States (Bangladesh, Bhutan, India, Nepal, Pakistan and Sri Lanka) are participated in the meeting. This book "Best Practices of Maize Production Technologies in South Asia" is a collection of papers contributed by experts from SAARC Member States.

I would like to take this opportunity to express sincere thanks to Dr.Thakur P. Tiwari, Country Representative, CIMMYT – Bangladesh for his guidance and support of this program. I would like to appreciate Dr. Pradyumna Raj Pandey, Senior Program Specialist (Crops), SAARC Agriculture Centre, Bangladesh and Dr. Keshav Babu Koirala, Maize Coordinator, National Maize Research Program, Nepal for their hard work to put together the manuscript in this form. I am confident that this compilation will facilitate further research and development in the best technology of maize crop in SAARC Region.

Dr. S.M. Bokhtiar
Director
SAARC Agriculture Centre

Foreword

Maize (*Zea mays* L.) is the main important cereal crop in South Asia. Because of diversified uses (e.g. food, feed and industrial processed food items, etc.) maize has been recognised as an attractive and emerging crop for the region. The demand for maize has been increasing steadily every year.

Maize researchers and development workers in the region are working collaboratively with the international organization like CIMMYT, and they have been very successful in developing technologies in tackling issues arisen from biotic and abiotic stresses experiencing by maize. As a result of participatory research and development efforts a basket of technological choices have been offered on variety, agronomy, plant protection, etc. for use by farmers as was seen from their respective country papers namely, Bangladesh, Bhutan, India, Nepal, Pakistan and Sri Lanka. This would not have been possible without a visionary leadership and dedicated researchers and the technological contribution to food security and livelihood improvement of millions of maize growers as a result of their efforts must be acknowledged.

Since, research is a continuous/on-going process, which requires committed long-term investment to address issues arisen from climate change and also meet the needs of maize growers and other stakeholders, which are keep changing. Therefore, considering production niche with respect to bio-physical and socio-economic, a concerted effort is further needed to identify maize genotypes that are higher yielding, earlier maturing for system compatibility/crop intensification, and tolerant to diseases, lodging, salinity, water-logging, and drought. The current effort of promoting mechanization based conservation agriculture for sustainable intensification and linking maize producers with market doesn't seem adequate, therefore needs further attention. There are certain policy issues hindering wider adoption of maize technologies that are beneficial to both the farmers and the environment, needed policy interventions. The role of private sector for the promotion of maize in the region is crucial therefore an enabling environment to attract private sector engagement/ investment be created.

The initiative of SAARC Agriculture Centre (SAC) to bring maize research leaders and providing a common plate-form to present their several years of results through video-conference was a great cross-learning opportunity, which is really commendable. I would like to congratulate all maize research leaders from the region and the SAC for an excellent arrangement to organise this event. Such events will certainly help increase cross-learning thereby addressing problems associated with maize and removing policy constraints constraining for a wider adoption of new maize technologies by farmers and stakeholders. Special thanks go to Dr Pradyumna Raj Pandey and Dr Keshab Babu Koirala for their technical editing and bringing the proceeding in a good shape.

Thakur P. Tiwari, PhD
Country Representative
CIMMYT - Bangladesh

Content

Executive Summary

Maize is the most versatile crop which is used as food, feed, fodder and in recent past as a source of bio-fuel. It has wide adaptability. Worldwide it is being cultivated in over 170 countries representing an area of 185 million ha with a productivity of 5.62 t/ha (FAOSTAT, 2017). Out of world maize production of 1037 million MT, SAARC countries comprising of Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan and Sri Lanka represent 3.2% with a productivity of 3.8 t/ha. Among SAARC countries, India represents the highest area (78.9%) followed by Pakistan (9.7%), Nepal (7.9%), Bangladesh (2.6%) and Sri Lanka (0.6%). The highest productivity of 6.9 t/ha is reported in Bangladesh followed by Pakistan (4.3 t/ha), Sri Lanka (3.4 t/ha), Bhutan (3.0 t/ha), India and Nepal (2.5 t/ha). During the decade covering 2005 and 2014, maize area and productivity in SAARC countries has increased at an annual compound growth rate (ACGR) of 2.2% and 5.2% per annum, respectively. The impressive progress of maize in SAARC countries is a result of increased demand in poultry and other feed industry rather than increase in demand for food. Maize R&D efforts in some of the SAARC countries are several decades old while in some like in Bangladesh, maize cultivation is more of recent introduction. Since these countries are in close proximity, the challenges like biotic or abiotic stresses are relatively similar. The need for technological interventions may also have resemblances.

On the other hand, SAARC countries are able to compete more vigorously in export markets and ensure benefits for a wide range of actors in the value chain of the maize crop. This provides opportunities and challenges to working in partnership with the CGIAR, the private sector, policy makers and other stakeholders to enhance efficiency and impact. Maize is high yielding, stress tolerant and nutritious. Sustainable Intensification of Maize-based Cropping Systems adding value for maize producers, processors, and consumers in South Asia would be a great socio-economic value for the improvement of livelihood of the farmers.

It is found that hybrid maize is an emerging high-value crop, having the highest average farm yields in Asia. Economically, hybrid maize is much more profitable than *Boro* rice, wheat, or most other competing *Rabi* crops. Although the crop can be grown both in *kharif* and in *rabi* seasons, but the potentiality of realizing very high yield is possible only during the *rabi* season, especially in Bangladesh. Maize cultivation is expected to expand driven by poultry, fish and cattle feed industry. It is now mainly grown in north-western, south-western districts and central regions of Bangladesh and the production is targeted mostly for poultry, fish feed and livestock which made this sector vulnerable. A series of

new technologies for sustainable and intensive maize production systems is emerging in Bangladesh of which some are being promoted and adopted quickly. The sustainability of hybrid maize production in Bangladesh depends on the use of quality hybrid seeds, good agronomic management, application of balanced fertilizers along with soil fertility conservation, and other management practices. Advances in molecular technologies and strategies, coupled with new tools for abiotic stress phenotyping, will provide a powerful combination for developing enhanced stress resilient maize for stress-prone agro-ecologies of the country as their severity and frequency increases.

In Bhutan, maize is cultivated by over 36,000 households for food and income. Maize has a larger area under cultivation as compared to rice and is also produced in larger quantities. The maize value chain shows that it is a subsistence commodity with as much as 94% being retained at home for consumption. Besides the maize grain, maize stover has multiple uses in their mixed farming system, from fodder to bedding material for cattle and ultimately contributing to organic manure. Thus, the food security role of maize cannot be understated. However, the trend is changing and with higher urbanization and higher incomes, preference for rice is increasing. Therefore, overtime, the importance of maize as a staple is likely to decrease. Maize has an industrial value and can be developed into a potential cash crop for the farmers if it can be produced in adequate quantities. The investment on maize commodity program in the 12th FYP should attempt to increase production with the scope to generate enough volume that can sustain maize using enterprises.

Likewise, the success story of maize in India and other SAARC countries over last two decades has remained phenomenal. The production has increased both due to significant increase in area as well as productivity. Genetic gain due to introduction of hybrids, more precisely single cross hybrids, and better crop management have contributed towards productivity enhancement. The drive behind the maize revolution in India and other SAARC countries is the demand of maize grain as feed, more particularly poultry feed. Though impressive signs of progress have been made a huge gap between potential and realized yield exists, which can be bridged only through up-scaling and out-scaling the proven technologies among the maize farmers. The maize R&D policy needs to follow a bottom-up approach with involvement of all stakeholders. Changing climate has brought a new dimension to the maize R&D scenario. Still, maize assumes better advantages than other cereals in addressing this challenge. India being strategically located with its long history of organized maize research may play an important role to lead the maize R&D in SAARC by sharing expertise, imparting training and acting as seed hub for the whole region. Government policies encouraging closer collaboration among SAARC countries will benefit not one country but all others as well.

In the case of Nepal, maize has been grown from Terai to mountain regions of Nepal. It is pivotal in food and nutritional security in mid and high hills; and feed and fodder security in Terai region of Nepal. New maize technologies are being developed across the globe and achievements are being shared through CIMMYT and other CGIAR partner organizations. New technologies identified, developed and verified by researches have been promoted by educational and extension systems. Because of similarities in agro-climatic conditions among SAARC countries, the technologies identified as promising in one country should be shared among each other for the benefit of the region. New technologies viz. hybrids, QPM, pro-vitamin A, resource conservation technologies; rational and scientific uses of inputs should be promoted aggressively.

In Pakistan, the planting/water conservation techniques being used in maize include ridge planting, bed planting, flat with line planting and broadcast planting. However, Ridge Planting (RP) is the best method for getting maximum grain yield per unit area. The parameters to be considered for getting maximum grain yield in maize include plant height (cm), number of leaves per plant, leaf rolling, leaf area per plant (cm^2), ear height (cm), days to 50% taselling, days to 50% silking, grain rows per ear, grains per row, ear length and girth (cm), 100 grain weight (g), stem girth at fourth internode, shelling percentage and grain yield (kg/ ha).

Maize is second important cereal in terms of cultivation extent and production in Sri Lanka. However, 80-85% of production used for poultry and cattle feed industry. The maize is given as the first priority crop under other field crops in research and development programs at Field Crops Research and Development Institute of DoA. The several OPVs and hybrids were developed in the country in collaboration with CIMMYT during last 40 years. Farmers are demanding hybrid maize seeds and 95% of maize area is under hybrid maize. The 95% of the total hybrid seed requirement is met by imported high yielding hybrids. Hence national average productivity has increased up to 3.6 t/ha. The main drawback is sustaining the productivity in maize lands due to land degradation and other abiotic and biotic stresses.

Therefore, SAARC Member States should be considered self-sufficient policy in maize production by increasing productivity through different strategic plans. The future focus of research is development of hybrid maize with high yield potential and giving special emphasis on stress resilience. As a result, amidst all the challenges and difficulties, cooperation and exchange of ideas, technology and vision among SAARC countries can bring food, feed and nutritional security, which is signicantly contribute the reducing poverty.

Challenges, Opportunities and Way Forward of Maize Industry in South Asia

Challenges

- Big yield gap (>3.5 ton)
- Hybrids - limited resources
- Seed demand - increasing but supply limited
- Poor human and physical resources
- Climate change (increased incidence of drought, heat, cold stress and flood)
- Low productivity of major cereals
- Limited varietal selection options
- Low seed replacement rate (SRR)
- Costlier quality seed
- Unavailability of required inputs as and when needed
- Increasing cost of inputs (fertilizers, seed, irrigation water etc.)
- Unavailability of labour and less mechanization
- Inadequate crop management technologies (e.g. plant population)
- Outbreak of new maize diseases (GLS) and insects (Pollen beetle)

Opportunities

- Diverse climate and production environments
- Diverse cropping patterns
- Scope of bridging the maize yield gap
- Ultimate food for mid hill people and raw materials for industries
- Diversity in uses (food, feed, fodder, fuel and other industrial uses)

There are five distinct emerging trends for the maize industry in SAARC countries. The challenges and opportunities for maize commodity thus hinges on these emerging trends:

i. Decreasing maize acreage
ii. Increase in overall maize production
iii. Declining consumption of maize as a staple

iv. Increase crop losses from natural calamities

v. Increasing demand for maize from in-country maize based enterprise

Way Forward for Maize Research and Development

Research

- Identification and adaptation of drought and heat tolerant maize varieties
- Identify short duration drought tolerant/escape varieties for double cropping system
- Research on different types of corn to identify suitable types for processing and product diversification
- Upscale research on post-harvest and processing with focus to minimize post-harvest losses for maize production
- Improved storage structures of maize
- Soil fertility and nutrient management technologies
- Identify and promote IPM technologies for major pests and diseases
- Promotion of hybrid maize technology in potential pockets
- Develop stress resilient technologies to tackle climate change issues (heat, drought, cold, diseases, insects etc.)
- Sharing of promising technologies among SAARC countries
- Double haploid production technology in maize
- Climate-smart agricultural practices with suitable agronomic and cultural management options and conservation farming systems for identified stressed ecosystems will be developed and disseminated
- Develop high yielding, pest and disease tolerant/resistant, medium-duration maize varieties which are input efficient (water and fertilizer) for favorable ecosystems and high temperature and water stress-tolerant for stressed ecosystems.
- sustainable management options for maize using conservation agriculture techniques for efficient use of available natural resources in most vulnerable AEZ's will be identified and disseminated to increase production through increased productivity and area under cultivation.

Development

- Commercialization of maize hybrids through contract farming and PPP model

- Promotion of community based seed production for improving the quality and quantity of maize seed
- Put in place as sustainable marketing mechanism through PPP model
- Development and promotion of maize based enterprises
- Support and promote initiatives on maize product development and processing
- Promotion of QPM varieties
- Promotion of extra early maturing varieties for green cobs for kitchen garden in non-traditional pockets
- Promotion of pop corn/baby corn/sweet corn varieties
- Introduction of grain/fodder maize in non-traditional areas
- Development of water logging, heat, drought, and lodging resilient maize varieties
- Establishment of maize based industry
- Introduction of bio-fortified maize varieties
- Strengthening of local seed industry
- Overcome post harvest problems
- Capacity building of maize researchers and extension workers
- Exchange of germplasm and technical guidance among the SAARC countries
- Human resource development with trainings and exchange visits for scientists, farmers and other stakeholders
- Allocate fund for maize research and development Cooperation and collaboration among SAARC countries for maize research and development.

Recommendations

Policy issues:

- Establishment of SAARC Maize Working Group towards regional cooperation; regional linking of source and supply to supplement export-import i.e. to have an on-line system for better connectivity among growers and consumers (poultry and starch industries); popularization of value added maize products through government schemes.
- Production of hybrid seeds locally to scale up locally developed hybrids
- Subsidizing or exemption of tax for maize based industry- starch, maize oil, etc. and Minimum Support Price (MSP) for maize producer.

- Training for young maize scientists in breeding and scientific agronomical practices
- Sharing of promising hybrids' lines for heat and drought tolerance
- SAARC annual workshop on maize program in the region
- CIMMYT should play pro-active role in implementing the maize program in the SAARC region
- Identified maize mega-environment within SAARC countries
- Encourage and promote Public-Private Partnership (PPP) for maize improvement and hybrid seed production
- Establish village based enterprises for implements, fertilizers, seeds and other inputs
- Scaling up of local hybrid seed production by providing technical and physical inputs
- Encourage private sector's participation for hybrid seed production

Technical issues

- Post-harvest management of weeds using tembotrione; identification of alternative seed hub to support hybrid seed requirement of SAARC countries; mechanization of planting, shelling, drying and entire post-harvest handling technology to reduce the labor cost
- Development of stress resilient hybrids-excess soil moisture, lodging tolerant, drought tolerant
- Promotion of hybrid technology through licensing and sub-licensing to private partners
- Develop ridge technology to maintain plant population and water saving/logging.
- Use of treated hybrid seed preferably single crosses
- Timely adoption of plant protection measure (weedicides, insecticides and fungicides)
- Mechanization of planting, mechanical weeding and harvesting; promotion of soil conservation package in rain fed uplands to increase productivity of maize
- Strengthening the development of high yielding and stress resilient local maize single crosses in collaboration with CIMMYT and SAARC Member States.

Scaling-up of Proven Technology for Maize Improvement through Participatory Approach in Bangladesh

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Introduction

Maize (*Zea mays* L.) is one of the most important cereal crops in Bangladesh and also the leading crop of the world after rice and wheat. About 75% of Bangladesh's population lives in the rural areas and their main sources of livelihoods are agriculture and the rural non-farm sector (World Bank, 2005). In order to achieve food and nutritional security for the increasing population, growing at the rate of about 1.6% per year, there is a call for increase in agricultural growth through higher productivity, agricultural intensification and/or diversification and value addition where maize can play an important role.

Although, the crop can be grown in both *kharif* and *rabi* seasons, but the potentiality of realizing higher yield is possible only during the *rabi* season. In *kharif*, farmers face various problems such as water logging, high incidence of diseases, pests, etc. However, *kharif* cultivation is also suitable in areas gradually increasing due to T. Aman-Potato-Maize cropping pattern.

The area under maize has been expanding since the early 2000s, driven by demand from the poultry feed industry and more than 98% maize areas are covered by hybrids (Karim, 2006). Only the tribal people in Chittagong hilly areas cultivate open pollinated varieties (OPVs). Most of the maize fields are irrigated, and farmers cultivate hybrid maize with improved production technology which is the secret behind higher production in Bangladesh. The challenge ahead is of a bigger magnitude as more people are added to current population (about 160 million) every year. Maize can and will play a dominant role along with other important cereals in meeting future food, feed and nutritional security. Maize is now mainly grown in north-western, south-western and central districts of Bangladesh and the production is targeted mostly for poultry, fish feed and livestock which made this sector vulnerable.

Agricultural Land Use

Like many other countries, soil is overwhelmingly the greatest national resource of Bangladesh on which its entire population depends for food supply. The major portion of the fabulously fertile agricultural land occurs on the vast floodplains of the Bengal delta formed by the deposition of sediments from the enormous rivers the Ganges, the Brahmaputra and the Meghna (GBM) and the Tista, all of which have been originated from outside the country (Rahman, 2002).

More than 60% of the land area of Bangladesh is used under agricultural purposes against only 12 % for the world (Rahman, 2002). This has been possible for the existence of the proverbially fertile soils on the few vast floodplains that are annually replenished by siltation during the flood. Two-thirds of the population in Bangladesh depends directly or indirectly upon agriculture, while nearly 25% of the gross national product comes from this sector (Rahman, 2002).

Land use in Bangladesh has evolved through natural forces as well as human needs. Cultivated land, forestland and settlements and homesteads are the major land use types in Bangladesh (Table 1). With the growing population, and their increasing needs in various sectors, land use patterns are undergoing a qualitative change in which the areas under the net cropped land, and forest land is gradually shrinking (Rahman, 2002).

Areas under double and triple cropping are showing an increasing trend over time. Cropping intensity is gradually increasing and stood at 192% in 2015-16 (BBS, 2016).

Table 1: Land Use Scenario in Bangladesh

Land Use Types	Area (million hectare)	% of total area
Total land area	14.763	100
Not available for cultivation	3.604	24.41
Forest	2.578	17.46
Cultivable waste	0.223	1.51
Current fallow	0.409	2.77
Double cropped area	3.915	26.52
Single cropped area	2.253	15.26
Triple cropped area	1.764	11.95
Net cropped area	7.950	53.85
Total cropped area	15.040	-

Source: BBS, 2016

The dominant food crop of Bangladesh is rice, accounting for 77.12% of agricultural land use followed by jute (4.59%) and potato (3.22%) (Table 2).

Table 2: Area And Production under Different Crops in Bangladesh during 2015-2016

Major crops	Area (million hectare)	% cropped area	Production (million ton)
Rice	11.39	77.12	34.71
Wheat	0.45	3.01	1.35
Maize	0.33	2.27	2.45
Pulses	0.37	2.52	0.38
Oilseed	0.46	3.09	0.93
Spices	0.40	2.68	2.49
Potato	0.48	3.22	9.47
Vegetables	0.40	2.72	3.87
Sweet potato	0.02	0.17	0.26
Jute	0.68	4.59	7.56
Sugarcane	0.10	0.67	4.21

Source: BBS, 2016

Soils of Bangladesh are moderately good and good agricultural lands together constitute the bulk of the land area in the country. Since there is an acute shortage of land in Bangladesh, still competition among the various land uses is natural. Agriculture, being the dominant land use type, is in constant conflict with other uses. Land type, area and proportion of Country’s total area are shown in Table 4. There are competitions for land within each use type. It is believed that, the declining productivity of soils is the result of depletion of organic matter (most soils have less than 1.7% organic matter) caused by high cropping intensity (Rahman, 2002).

Area and Production Status of Maize Crop

Demand of maize in Bangladesh is expanding rapidly, outpacing increasing production rate. Before 1971, maize cultivation was mainly limited to a few tribal areas of the southeastern Chittagong Hill Tracts. The rapid expansion of the poultry industry in the 1990s increased the demand for maize grain as poultry feed and farmers, particularly in northern and western parts of the country, adopted maize as a cash crop.

Table 4: Land Type, Area and Proportion of Country`s Total Area

Land type	Area (million hectare)	Proportion (%)
Highland	4.199	29
Medium Highland 1 & 2	5.039	35
Medium Lowland	1.771	12
Lowland	1.101	8
Very Lowland	0.193	1
Total Soil Area	12.305	85
River, Urban, Homesteads etc.	2.178	15
Grand Total	14.483	100

Source: FAO, 1988

Maize area planted in Bangladesh has risen from just a few thousand hectare in 1993-94 to a total of 0.396 million hectare in the 2016-17 and approximately 3.578 million metric tons of maize grain was produced (Figure 1). The current estimates of maize demand stand at 2.00 million metric tons annually (Source: personnal communication). With the introduction of hybrids and adoption of appropriate crop management practices, production and yield of maize has increased from an average of less than 1.0 ton per hectare for several decades through 1992 to 7.46 tons per hectare in 2016-17. Maize is now mainly grown in north-western, south-western and central districts of Bangladesh of which Rangpur division occupied the highest areas followed by Khulna and Rajshahi (Figure 2).

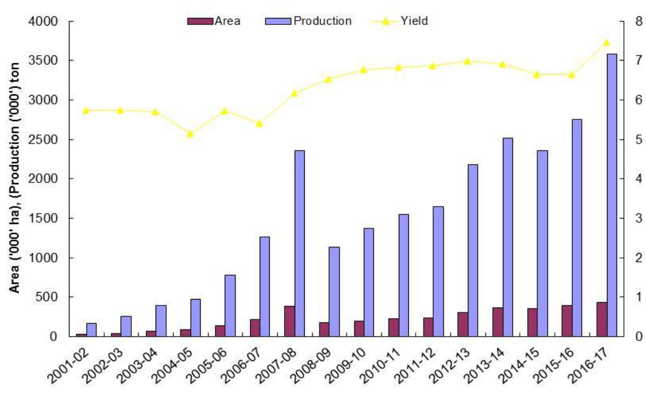

Fig. 1: Area, production & yield of maize during 2001- 2017

Source: DAE, 2017

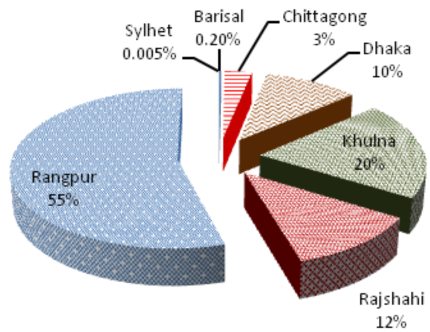

Fig 2: Distribution of maize area by divisions in Bangladesh during 2015-2016

Source: BBS, 2017

The potential for increasing maize area in Bangladesh is high. Of the total cropped area of 15.04 million hectares, it is estimated that nearly 2.32 million hectare (24% of cultivable area) are suitable for maize cultivation (Hussain et al., 2012) (Figure 3 & Table 5). Ali and his colleagues (2008) reported that most of the country is suitable or moderately suitable for maize cultivation, based on soil and climate (Figure 4).

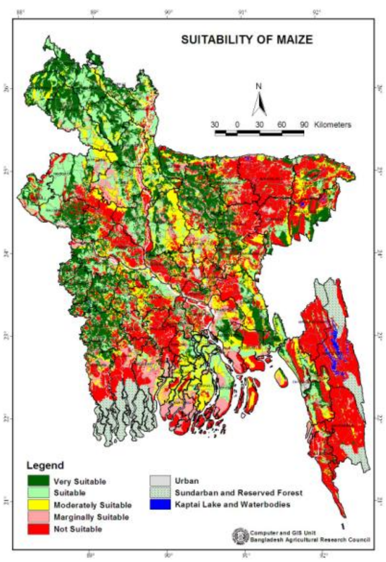

Fig. 3: Potential suitable area for maize

Source: Hussain *et al.*, 2012

Fig. 4: Maize suitability map of Bangladesh.

Source: Ali *et al.*, 2008

Table 5: Areas under Different Suitability Class for Maize

Suitability classes	Million hectare	Percent of cultivable area
Very suitable (VS)	2.32	24
Suitable (S)	2.04	21
Moderately suitable (SM)	01.52	16
Marginally suitable (LS)	0.86	9
Not suitable	03.05	31
VS+S	4.36	45
S+MS	3.56	36
VS+S+MS	5.89	60

Source: Hussain *et al*., 2012

The major amount of maize produced is being used as poultry feed (Hossain and Shahjahan, 2007) and a portion for fish feed although some dairy farms use maize as feed grains and its plants as green fodder. Financial returns ha^{-1} from *Rabi* season maize are 2-3 times more than those of wheat or boro rice (Moniruzzaman et al., 2009). The area planted for maize in Bangladesh has expanded at 16% per year over the last five-year period, a growth rate faster than for any other crop.

In addition to favorable prices, the growing scarcity of water for irrigation also has forced the farmers to shift from wheat and *Boro* rice to maize. The maize growing season does conflict with growing seasons for wheat and *Boro* rice, and other cash crops like potato, and winter vegetables.

Genesis of Maize Improvement Program in Bangladesh

Maize research in Bangladesh was initiated on a modest scale in the early fifties with the introduction of some popcorn and sweet corn varieties from the United States with a view to popularize maize in this region by the Economic Botany (Fibres) Division of the East Pakistan Directorate of Agriculture (EPDOA). However, after the introduction of HYVs of wheat and rice in the 1960s and 1970s maize research was not considered a priority. After the establishment of the Bangladesh Agricultural Research Institute (BARI) in 1976, maize research and development program got renewed thrust with a view to develop high yielding varieties. Many germplasm from Inter Asian Crop Improvement Program (IACIP), International Maize and Wheat Improvement Centre (CIMMYT), Tropical Asian Maize Network (TAMNET) and FAO-UNDP were introduced and tested in different research stations of BARI

(Hossain and Sarker, 2001). Initial thrust was given for the development of OPVs as it has an advantage over hybrid in greater convenience of seed multiplication. Some of the composites were identified for their reasonably good yield potentiality and wider adaptability. During the period between 1986 and 2013, BARI has developed and released 9 composites including field corn, popcorn, sweet corn and baby corn of which some have got popularity among the farmers.

Since early nineties, the research strategy of this division was directed from composite and synthetic towards the development of hybrids. Inbred lines were introduced from different international research organizations like CIMMYT, CIMMYT-ARMP (CIMMYT Asian Regional Maize Program, Thailand), IITA (International Institute for Tropical Agriculture, Nigeria) and KU (Kasetsart University, Thailand) and evaluated them for the development of hybrid varieties. The released inbred lines are being maintained and early generation lines have been advanced. Programs have also been taken up for the development of inbred lines from locally using hybrids and OPVs. Promising single crosses are being recycled for extraction of superior inbred lines (Hossain and Sarker, 2001).

In the meantime, both exotic and locally developed lines used for development of single cross and top cross hybrids and a good success have been achieved. Besides inbred line development, maize improvement program of BARI has also been testing exotic hybrids through international trials with a view to identify better performing hybrids. Using introduced and locally developed inbred lines; BARI has so far developed 15 hybrids from 2000 to 2017 of various kinds (Table 6). Yield potentiality of the released hybrids ranges from 7.5 to 12.75 tons/ha under favorable conditions. Recently program has been initiated to develop base population as a source of elite inbred lines from promising hybrids of different origin. Research is now going on to find high yield potentiality, short duration and medium tall variety in wider agro climatic condition.

In Bangladesh, plant breeding and variety development of maize is usually carried out by plant breeders in the public research institutions and to some extent in large seed companies. Plant breeding division of BARI has a solid and systematic program and is now leading the maize research in Bangladesh. Different universities, NGOs and private companies conducting maize research in sporadic manner and in a limited scale. Universities' research is mainly confined by the MS or PhD students. Because of fund limitation, the universities focus more on teaching than on research.

BARI is partnering with the Bangladesh Rural Advancement Committee (BRAC), Lal Teer Seed Ltd., Supreme Seed Co. Ltd., ACI Seed and Krishibid Seed through two specialized projects namely, Heat Tolerant Maize for Asia (HTMA) and Climate Resilient Maize for Asia (CRMA) (personal communication), led by CIMMYT.

Table 6: List of Hybrid Maize Varieties Developed during 2002-2017

Hybrid	Yield (t/ha)	Maturity	Year of release	Type of cross
BARI hybrid maize 1	8.5-9.5	140-150	2002	TWC
BARI hybrid maize 2	8.0 -9.0	145-150	2002	SC
BARI hybrid maize 3	9.5-10.0	145-150	2002	SC
BARI hybrid maize 4	7.5 - 8.5	140-145	2002	TC
BARI hybrid maize 5	9.5 - 10.0	140-145	2004	SC
BARI hybrid maize 6	9.5 - 10.0	140-145	2006	TWC
BARI hybrid maize 7	10.5-11.5	140-145	2006	SC
BARI hybrid maize 8	10.5 -11.5	145-150	2007	SC
BARI hybrid maize 9	11.5 -12.5	145-150	2007	SC
BARI hybrid maize 10	10.0 -11.5	145-150	2009	TC
BARI hybrid maize 11	10.5 -11.5	150-155	2009	SC
BARI hybrid maize 12	8.1-8.5 (single irrigation) 10.0-11.1 (normal irrigation)	140-145	2016	SC
BARI hybrid maize 13	8.2-8.9 (single irrigation) 10.1-11.2 (normal irrigation)	145-152	2016	SC
BARI hybrid maize 14	10.84 (rabi); 10.52 (kharif)	140-145	2017	SC
BARI hybrid maize 15	12.75 (rabi); 12.07 (kharif)	145-150	2017	SC

TWC= Three way cross; SC= Single cross; TC=Top cross

Source: Plant Breeding Division, BARI, Gazipur

BRAC, an NGO, started maize research activity since early 1996 in a limited scale in collaboration with CIMMYT. With their small effort BRAC has so far released few maize hybrids (Uttaran, Uttaran-2, Uttoran-3 and Uttaran Super) by the national seed board of the government which is now being marketed locally. Besides that BRAC has an extensive collaboration with Advanta Seeds (former Pacific Seeds) of Australia, Thailand and India and works more or less on commercial basis. BRAC receives the parental lines of hybrids from Advanta Seeds for production of F_1 seed in Bangladesh and pays royalties based on production figures. Supreme Seed Co. Ltd. is doing research in a very limited scale and has so far developed and commercialized one maize hybrid (Heera Super 112). Most of the companies are doing adaptive trials from imported hybrids for introducing new varieties. It is not surprising that most of the private sector seed companies prefer importation rather than production of seed and R&D because of lack of regulation to this effect.

All the commercially cultivated and most of the BARI released varieties are yellow grain types, although recently three white kernel varieties have been released. BARI has also initiated work for the development of white grain QPM (Quality Protein Maize) for making chapatti/roti for human consumption. Research work is also going on to develop high yielding exportable quality hybrid baby corn, pop corn and sweet corn varieties. This division is now also giving thrust to develop different abiotic stress resilient maize varieties to address problems of excess soil moisture, heat, drought and saline soils. Recently two drought tolerant and two heat tolerant hybrids have also been released to tackle the problem of climate change. Biotechnological interventions such as marker-assisted selection, gene transfer using *Agrobacterium tumefaciens* have also been initiated to develop maize varieties targeting specific objectives.

Maize Production Technology, Post-Harvest Handling, Value Addition and Other Improved Technologies for Research and Development

Maize Production Technology

Land & soil: A deep loamy soil, high in organic matter and plant nutrients is the best soil but maize can be grown successfully on any soil from loamy sand to clay. It can be grown successfully on soils with a pH from 5.0-8.0, but 6.0-7.0 is optimum. If the soil pH is low, liming might be necessary.

Seed rate: The recommended seed rate is 20-22 kg/ha for grain production.

Seed treatment: The most common fungicides used for seed treatment are Furadan and Arasan M. Seed can be treated by 50 ml of Furadan 30% (seed treater), 2 g of Arasan 75% (wettable powder) and 12 ml of water per kilogram of seed. Seed can also be treated by Provax 200 WP @ 2.5 g/kg seed.

Time of sowing: Optimum time of sowing in rabi season is from mid October to 1st week of December, in kharif I from mid February to end of March and in kharif II from mid July to mid August.

Land preparation: Maize can be cultivated with normal land preparation or with minimum or zero tillage. Under normal condition 2-3 ploughings followed by laddering are adequate for sowing. BARI bed planter could be a good option for bed formation, fertilization and seeding in a single cross.

Sowing method: Seeds should be sown in rows and in Bangladesh, it is recommended to plant in rows 60 cm apart with a plant to plant spacing of 25 cm with one plant per hill which gives 66,666 plants/ha. In flood prone areas sowing can be done by dibbling method under zero tillage condition after receding of floodwater.

Fertilizer application: Fertilizer application depends on fertility status of the soil where the crop is grown as well as the nutrient requirement of the variety. However, in Bangladesh for hybrids the recommended dose of N, P, K, S, Zn and B per hectare, respectively, are 250, 55, 110, 40, 5, 1.5 kg/ha. One third of N and other fertilizers are applied as basal. Remaining two third of N should be applied in two installments: One third at floral initiation (Knee height/8-10 leaf stage) and the rest at about one week before silking or grain filling stage. In case of dibbling method of planting, initial dose of fertilizers can be applied in the pits, 10 cm apart from the plants. The second and third doses of N can be applied as mentioned in two installments. For better yield 4-6 tons of FYM/ha should be applied.

Irrigation: Single irrigation at each of growth stages i.e. within a day of planting; at knee height stage (8-10 leaf stage); a week before silking or when male flower is visible; and about two weeks after silking or grain filling, are necessary for higher yield. Water logging at any stages of growth is detrimental to maize. During summer if the crop is sown before onset of rains, a pre-sowing irrigation is required for better germination and crop establishment. Under heavy rainfall conditions, drainage is must.

Intercultural operation: For a good stand, over planting and then thinning at crop establishment stage is practiced. In case of over-planting, thinning to a desired plant population should be done within two weeks of germination or when the seedlings are about 15 cm tall.

Care should be taken not to disturb standing plants at the time of thinning operation.

Earthing up of plants is one of the most important operations in maize cultivation. The furrows made out of this operation could be used as drainage or irrigation channels, depending on the needs. This operation can be performed with the help of spade at the time of application of the second dose of N at knee height stage of the crop.

Weed control is essential to ensure good harvest. In Bangladesh, weeds cause more problems in the summer than in the winter. First weeding should be done within 15 days of sowing. Another 2-3 weedings may be required depending on the degree of weed infestations during different life cycle of the crop. Maize farmers of Bangladesh practice manual weeding when weed infestation is very high.

Pest management: The important diseases appear during seedling, growing and maturity stages of maize are: 1) Seed rot and seedling blights; 2) Leaf blight; 3) Yellow leaf blight; 4) Stalk rots; and 5) Ear rot and kernel rot. Application of proper fungicide is essential to control these diseases. Tilt or Folicure @ 0.5 ml per liter of water should be sprayed 3-4 times at 15 days interval to control leaf blight and leaf spot diseases, starting when lesions are first observed.

Control of both above and below ground insects as well as stored grain pests is essential in maize for good crop production. Major insects are: 1) cut-worm; 2) fall armyworm; 3) maize aphid, 4) stem borer; and 5) maize weevil. Dursban or Pyrifos 20 EC @ 5 ml/litre water should be sprayed especially at the base of plants to control cutworms. The larvae can also be killed after collecting from soil near the cut plants in morning. Poison bait could be used to control maize cutworms. Poison bait is made by mixing Carbaryl 85wp @ 2 kg/ha with 100 kg wheat or rice husk. Poison bait may be applied in the evening. Applying proroclein-5SG or Emacor-5SGinsecticides @ 1 g per liter of water from the top of affected plant effectively control the fall armyworm. To control stem borer, Furadan 5G @ 20 kg/ha or 3/4 granules per plant should be applied on whorl. Besides, pheromone traps can be used from seedling stage setting at 10 m^2 distance to control stem borer. Application of Phostoxin tablet @ 3-6 tablets/ton grain may be applied for controlling maize weevil.

***Harvesting*:** Harvesting should be done when kernels reach physiological maturity showing black layer on the tip of the kernel. Maize is commonly harvested with 15 to 25% moisture content of the kernels. Harvesting fully mature grain will result in maximum yield, improved appearance and reduced post-harvest losses. In Bangladesh, harvesting is done manually.

Post-Harvest Handling in Maize

In Bangladesh, a large portion of maize is harvested during rainy season and thus wet grains are affected by rots and molds, and aflatoxin resulting reduced market price. The aflatoxin affected grains could be harmful for poultry and as well as for humans. Immediately after harvest, the plants are cut just above the ground; cobs are dehusked and sundried for about 2-3 days. Dried cobs are shelled either by corn sheller or manually. Farmers shell their maize cobs by sickle or rubbing with a basket which is very laborious and time consuming. Both manually and power operated sheller can be used and BARI developed hand and power maize sheller is a good option. The shelled kernels are dried again before storing at optimum moisture level i.e. below 12%.

There is limited storage facility at government level (at BADC), traders, processors, and NGOs. Wholesalers, stockiest, *Arathdars*, and NGOs store their maize according to their needs. The farmers neither have good storage facilities nor the means to store their product for a longer period and sell it when the price rises.

Value Addition in Maize

Maize is the most versatile multi-use cereal for diversity of value-added products and end uses. Maize grain provides several opportunities for Bangladeshi farmers to increase their income from its use in poultry feed, fish feed, or cattle feed, and its mixture with wheat flour for making chapatti/roti. Whole cobs can be roasted or specialty corn consumed as popcorn, baby corn, sweet corn etc. QPM and bio fortified (pro vitamin A, Fe & Zn) maize based products can also create value addition at producer and national levels. Maize can also be used for corn flakes, oil extraction, corn starch and syrup, and as a feedstock for bio-ethanol. Current major uses of maize in Bangladesh are mainly feed for poultry, fish and cattle and fodder for livestock as well. Stems and bare cobs are a high energy fuel. Future work should look at the prospects and benefits, and raise awareness about some of these other uses in Bangladesh. Through improving the efficiency of the value chain, industry profits and employment can be generated, demand can be expanded, and farmers can get better prices.

Profitable Intercrop/Relay Crop Options with Hybrid Maize

Rabi season hybrid maize is a long duration (145-150 days) crop, but resource poor farmers want quick returns from their investment. The maize crop is spaced on rows 60 cm apart and canopy closure happens only after 45-50 days. Through intercropping/relay cropping of maize, the productivity per unit area of land could be increased considerably.

During this early period of maize crop, the production of quick growing vegetables such as spinach and red amaranth is very feasible and economical; it provides early additional income without reducing maize yield when grown as a sole crop (CIMMYT Bangladesh, 2005; 2006). Relay cropping of maize after 20-35 days of potato planting can bring very high profit, providing 20-21 t/ha maize equivalent yield within five months (CIMMYT Bangladesh, 2005; 2006). Thus intercropping and relay cropping are becoming more popular among the subsistence farmers. Such diversified and highly profitable systems can be promoted.

Potential Scaling Up Of Proven Technologies for SAARC Countries

Cultivation of locally developed maize: BARI has so far developed 15 hybrid maize varieties as well as 9 OPV's of various kinds but very few have been commercialized. Private seed companies, public sector seed production agencies, and NGOs, can take forward the hybrids for licensing, followed by seed production and large-scale scale-out among maize farmers.

Dissemination of stress resilient varieties in the targeted areas: A good number of abiotic stress resilient maize hybrids (heat and drought) have so far released by BARI. Few more varieties are yet to develop focusing excess soil moisture and saline soils. Due to the changing environment these varieties can effectively be deployed in the targeted regions through public private partnership.

Dissemination of modern production technology: The plant breeding division along with other relevant divisions of BARI has already developed complete production package of technologies for maize at farm level. These can be demonstrated through DAE both at public and private sector for comparison (FGD, 2013). This initiative obviously makes farmers enthusiastic toward higher maize production.

Application Boron on light soils of maize of the northern region: Boron (B) is an important micronutrient needed in small amount for grain formation. In B-deficient soils of northern Bangladesh and in char (seasonally flooded river bed and floodplain) areas, it must be applied to raise the efficiency of use of macro nutrients (NPKS) and to obtain better yields. In those conditions, by applying 2 kg B per hectare, grain yields of maize can be doubled, compared to those without B.

Application of lime in hybrid maize seed production: At present more than 30% lands of this country have acidity constraint for crop production. Lime application improved crop yields by eliminating the production constraints and favoring the production factors related to nutrient availability. Soil scientists of BARI have recommended 2.0

tones of lime per hectare for minimizing soil pH and better crop production.

Introduction of maize based cropping patterns: BARI has developed some suitable maize based cropping patterns which ensure higher yield and financial return compared to traditional cropping pattern.

Promotion of intercropping and relay cropping: Intercropping and relay cropping of maize are very much profitable and acceptable to the resource poor farmers. BARI has developed some maize based intercropping and relay cropping practices which are found to be more profitable. The Agronomy Division of BARI has developed maize intercropping systems e.g., with red amaranth, spinach, chickpea, and bush bean.

Improve post-harvest management practices*:* Farmers of Bangladesh generally complete the post-harvest work manually. Maize shelling and drying are the two crucial steps in post-harvest operations. Growing maize during the summer seriously faces the problem of drying due to rainy season. Mechanical sheller (manual and power) and low-cost dryers (i.e., STR dryer) can play an important role in this aspect.

Introduction of mechanized planter and bed system planting*:* There is an ample scope of introducing mechanized planter and raised bed technology in maize production to increase the yield. The turnaround period between T. Aman rice and maize is very short. In Bangladesh, farmers are practicing bed planting system for potato, maize, chilli vegetables etc. from long ago to protect crops from water logging problem due to heavy shower. BARI bed planter attached with power tiller can till soil, make bed, apply fertilizer and sow seeds simultaneously in a single operation.

Maize flour for human consumption: In this context, existing flour mills in the country may be oriented for the production of mixed flour with wheat and maize.

Maize for animal feed: Animal feed in the country is severely deficient due to the lack of an organized feed industry and non-availability of grazing land. Thus, maize could play a significant role as animal feed and fodder or as silage. Using BARI maize chopper block can be made mixing liquid molasses (50%) with chopped dried maize plant (50%) which could be suitable to feed livestock during lean period.

Dibbling maize in flood prone areas: Maize can be dibbled in the flood prone areas as soon as flood water recedes without waiting for the soil to dry, at a time when no other crop would grow. Maize can be grown in these areas under no tillage and with minimum inputs.

Key Policy Input for Improvement of Proven Technology of Maize Crop in South Asia

Improvement of research and extension linkage: The linkage between research and extension is very weak. Therefore, Government needs to take some steps to improve this linkage to disseminate technologies to the end users.

Impact of information and training on maize yield: Training and information regarding crop production can play a vital role in attaining higher yield. A study conducted by CIMMYT in Bangladesh (2006), shows that the farmers after receiving training on maize cultivation obtained 17.31% and 15.4% higher yield during 2001-2002 and 2004-2005, respectively compared to pre-training period.

Development of local seed industry: Maize growing areas in Bangladesh are mostly covered by a wide range of foreign hybrid varieties. Development of local hybrids and production and expansion of these hybrid seeds will reduce import and thereby save foreign currency and farmers would also be able to buy good quality seeds cheaply and timely. A stable policy needs to be formulated to attract both the public and private sectors to the maize seed industry.

Change in Government policy: Government should encourage the private sectors to build up maize based industries for the production of starch, flakes, corn oil, etc. Credit and exemption of taxes on equipment and machinery for these industries should be introduced.

Fund for maize research: Increasing maize production using locally developed hybrids is a serious concern of the government. Although current Government of Bangladesh has allotted funds for quality research work but to fulfill the current demand and future needs more funds should be invested.

Credit for input: Farmers do not have enough access to formal sources of credit for various inputs like, seeds, fertilizers, farm machineries, etc. Government should take proper initiatives so that the farmers have an access to the credit of the institution without any collateral requirement. For this government can follow the strategies of NGOs working in Bangladesh.

Involvement of mass media: To encourage increased human consumption of maize based food, special motivational programme (e.g., drama, short film, advertisement, etc.) may be initiated in the media like television and radio.

Challenges and Way Forward for Maize Research and Development in South Asia

Challenges

High dependency on poultry, fish and cattle feed sector: Future demand for maize will largely be an outcome of the growth of poultry, fish and cattle farm. Reduced consumption of feed will affect maize growers as the price of the grain, the main ingredient for feed, is driven by the demand of feed millers.

Competition with winter (*rabi*) crops: The main cereal food item is rice and farmers grow *Boro* rice in winter season. Despite that, a variety of high value crops are also grown in the winter season. So, maize has to compete with these high value crops along with *Boro rice* in terms of crop choice by the farmers.

Dependency on foreign hybrid seed: Due to the rapid expansion of the feed industry as well as maize growing areas, the demand of hybrid maize seeds increased over the years. But major part of this demand is being fulfilled by importing since domestic production could hardly meet 8 to 10% of the total requirement. Any problems related to import may badly hamper its production all over the country.

Higher price of hybrid seed and production inputs: As the demand for hybrid seed is very high, the multinational companies and local seed importers are doing monopoly business. The price of hybrid seed is thought to be very high, ranging from Tk 300 to Tk 450 (USD 3.75-USD 5.62). Besides that, fertilizers, irrigation, labour cost are also going high day by day.

Lack of awareness: High yielding and good quality seed is a pre-requisite for maximizing maize yield. Farmers generally identify quality seed through observation, past experience, consulting with neighbors, and trust on seed dealers at the local or nearby markets which sometimes motivate them to buy adulterated seed.

Limited access to financial institutions: Farmers do not have enough access to state owned financial institutions due to many rules and regulations. The maize farmers need agricultural credit at lower cost since its cultivation requires high inputs.

Faulty marketing system: There are no organized farmers' commodity markets or a single place for bulk procurement of maize. Usually it has to be procured directly from farmers or through middlemen which hamper the regular availability or may cause price fluctuations. Bangladesh government procures rice and wheat directly from farmers and traders at a declared fixed price in each year to accumulate large stock for meeting country's emergencies and to control over the price. The same policy should be followed for maize too.

Scarcity of labour: Currently the non-farm sector is well developed in Bangladesh. A significant portion of wage labourers has been shifted to non-farm sector resulting in scarcity of wage labourers in agriculture. Agriculture sector still is not mechanized and cultivation of maize requires a high amount of labour which increases the production costs.

Lack of cultivable land for small land owners: Most of the farmers of Bangladesh are small land holders. They cannot expand their maize production, even if they have the investment capacity and opportunity only because of the lack of enough cultivable land.

Deterioration of soil health, adulteration of fertilizers and maize yield: Application of balanced dose of fertilizers is one of the key factors for obtaining high and profitable yield of hybrids. Most resource-poor farmers are applying N fertilizer at rates near the optimum, but under-dosing other essential macro and micro nutrients (Ali *et al*., 2008). Fertilizer traders sometime adulterate fertilizers with inert ingredients and it happens mostly in case of micro-nutrients (Boron, Zinc, etc). Sometimes shortages of fertilizers encourage traders to adulterate fertilizers also. These are detrimental for soil health and maize productivity.

Impact of climate change on maize yield: Many maize areas of Bangladesh are prone to various biotic and abiotic stresses. We have already seen an increase in temperature and rainfall averages, more frequent and intense monsoons and cyclones, drought and saltwater intrusion in inland areas. The water logging problem is mainly associated with *Kharif-1* maize production. Up to 23% of Asia's maize crop could be lost due to higher temperatures by 2050 (Prasanna, 2013). Bangladesh is also facing a problem of salinity due to climate change which also hinders maize area expansion in the southern region. Besides that high velocity wind affect maize production to a greater extent caused by lodging. The northwestern districts (Greater Rangpur, Dinajpur and Barind Tract of Rajshahi) of the country, popularly known as North Bengal, are the drought prone areas (Murshid, 1987) where maize is being intensively cultivated. So, we need varieties to cope with these changing climates.

Post-harvest management of maize: In Bangladesh, a large portion of maize is harvested during rainy season, which often makes the cobs and grains wet (containing 20-25% moisture). In this situation, wet grains are affected by ear rots and molds caused by fungus, and consequently aflatoxin are a serious concern. These reduce the market price of maize grain, and could be harmful for chickens as well as humans.

Unavailability of ground water and high prices of irrigation: In Bangladesh, major maize growing areas is under *rabi* cultivation which is grown with irrigation using mostly underground water. Scarcity of underground water and high prices of irrigation makes it difficult for the farmers to grow maize profitably.

Outbreak of pest and diseases: Although maize is still relatively problem-free in Bangladesh, but with the increasing areas and production, and introduction of exotic maize varieties every year the crop is under threat of new diseases and pest which might come as a serious problem in the near future.

Way Forward

Development of water logging, heat, drought, and lodging resilient maize varieties: The development of short-duration, water logging, heat, drought and lodging tolerant maize varieties with high to moderate grain yield potential should give high priority in responding to climate related environmental changes as their severity and frequency increases. Scientists of BARI are working hard to find out suitable stress resilient maize varieties considering the current demand and future need and very recently identified and released few stress resilient varieties (drought and heat) which are yet to reach in farmer's field.

Establishment of maize based industry: The immediate prospect of using maize in the industry lies in the use of maize as raw materials for starch industry, corn oil industry, breakfast cereal industry and confectionary (Islam and Kaul, 1986). However, maize as a feedstock for starch for the garments industry is a more practical and likely major market in the near future. Corn starch is also identified as one of the ingredients for manufacture of biodegradable plastic.

Introduction of bio fortified maize varieties: QPM and bio fortified **(**Pro-vitamin A, Fe, and Zn enriched) cultivars are now available at the CIMMYT global maize program. If those cultivars could be adapted in Bangladesh and South Asian regions, it would be a very good source of these nutrients for humans and others.

Strengthening of local seed industry: Bangladesh is in favorable situation to expand and develop a strong and efficient maize seed industry. Development of local seed industry will reduce import and thereby save foreign currency and farmers would also be able to buy good quality maize seeds at a fair price and timely availability can also be ensured.

Overcome post harvest problem: Low cost drying and use of mechanical dehusking and shelling can improve the quality of maize seeds and help farmers to overcome the problem regarding aflatoxin emerged as a problem in maize cultivation.

Capacity building of maize researchers and extension workers: Quality output from working scientists is of immense importance. Maize scientists should get exposure opportunities for research and training facilities at home and abroad for broadening their knowledge. Scientists should get support for regional training events on maize regarding breeding, seed production, and technology transfer. Arrange visiting program of maize scientists, experts and field level workers between South and Southeast Asia would also be effective in sharing knowledge.

Exchange of germplasm and technical guidance: Exchange of maize germplasm and technical guidance to upgrade maize breeding programs in South Asia through a strong partnership will solve problems regarding changing environment and other related issues.

Training of farmers and stakeholders: Highly potential productivity of maize in Bangladesh has yet to be fully achieved. In cultivating of hybrid maize, information and technology needs to flow to and among farmers. The maize whole-family training (WFT) approach in training farmers in Bangladesh proved the importance of training for the farmers and other related stakeholders for quick and effective dissemination of technology.

Allocated fund for maize development: More funds to be allocated for research, extension, marketing and procurement of maize. A good marketing system need to be established, with a support price scheme.

Conclusion

In Bangladesh, hybrid maize is an emerging high-value crop, having the highest average farm yields in Asia. Economically, hybrid maize is much more profitable than *Boro* rice, wheat, or most other competing *Rabi* crops. Although the crop can be grown both in *kharif* and in *rabi* seasons, but the potentiality of realizing very high yield is possible only during the *rabi* season. Maize cultivation is expected to expand driven by poultry, fish and cattle feed industry. It is now mainly grown in north-western, south-western districts and central regions of Bangladesh and the production is targeted mostly for poultry, fish feed and livestock which made this sector vulnerable. It is expected that alternative uses of maize will increase in the near future. Maize-*T. aman* (monsoon) rice is the major cropping system; however, it is now becoming diversified with many other crops including potato, mung bean, mustard, etc. Maize is still cultivating in Bangladesh as relatively problem-free crop, but some problems are intensifying with increased concern like insects, diseases, deterioration of soil health and adulteration of fertilizers which might have negative impact for the expansion of the crop. A series of new technologies for sustainable and intensive maize production systems is emerging in Bangladesh of which some are being promoted and adopted quickly. The sustainability of hybrid maize production in Bangladesh depends on the use of quality hybrid seeds, good agronomic management, application of balanced fertilizers along with soil fertility conservation, and other management.

Advances in molecular technologies and strategies, coupled with new tools for abiotic stress phenotyping, will provide a powerful combination for developing enhanced stress tolerant maize for stress-prone agro-ecologies of the country as their severity and frequency increases. More regional co-operation should be made in terms of technology transfer, capacity building and exchange of germplasm, data and information which are quite indispensable. Increase investment in the research and development of maize will certainly encourage scientists to develop suitable maize technologies. Government should support private seed companies, and NGOs to strengthen their research, seed production and public private partnership. Effective linkage between research organization and department of agricultural extension should be established for successful dissemination of developed technologies to the end users.

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Scaling-up of Proven Technology for Maize Improvement through Participatory Approach in Bhutan

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Introduction

Bhutan is a small landlocked mountainous country located in the southern slopes of Eastern Himalayas. The country lies between latitudes 26°42^{0}N and 28°14^{0}N, and longitudes 88° 44^{0}E and 92°07^{0}E. The country has a total geographical area of 38,394 square kilometers with a population of 745,600 people. The forest cover of the country is about 70.46% but the cultivated land is only 2.93% of the total area (LCAR, 2010). Agriculture is the mainstay of the people with an estimated 69% of the population engaged in agriculture. Rice, maize, wheat, barley, buckwheat and millets are major cereal crops cultivated in Bhutan, however rice is by far the most important and preferred food crop. Agriculture is very important to the Bhutanese economy; the sector accounted for 16.7% (NSB, 2016) of the total GDP of the country in 2011 (RNR Stats, 2012). Majority of the Bhutanese farmers continue to practice self-sustaining, integrated and subsistence agricultural production system with small land holdings where farmers grow a variety of crops under different farming practices and rear livestock to meet their household food and nutritional security.

Agricultural Land Use

Bhutan is a mountainous country which can be divided into three altitude zones: The Sub-Himalayan Foothills; The Inner Himalayas; and The Greater Himalayas ranging from about 150 meters in the south to about 7000 meters in the north. The three broad altitudinal zones display different agro-ecological and climatic zones, determined by physiographic and climatic conditions. Although a small country, Bhutan experiences a wide range of climatic conditions favorable for different agricultural practices.

Out of total land area 70.46%is covered by forest, 2.93% by agriculture, 3.2% by bare areas, 0.2% by settlements, and about 7.4% by snow, .7% by water bodies. (NSB, 2011) Land resources include both physical and biological resources in land and water. Physical resources encompass soil and mineral resources, while biological resources include flora and fauna. Flora and fauna include both wild and domesticated species and genetic resources.

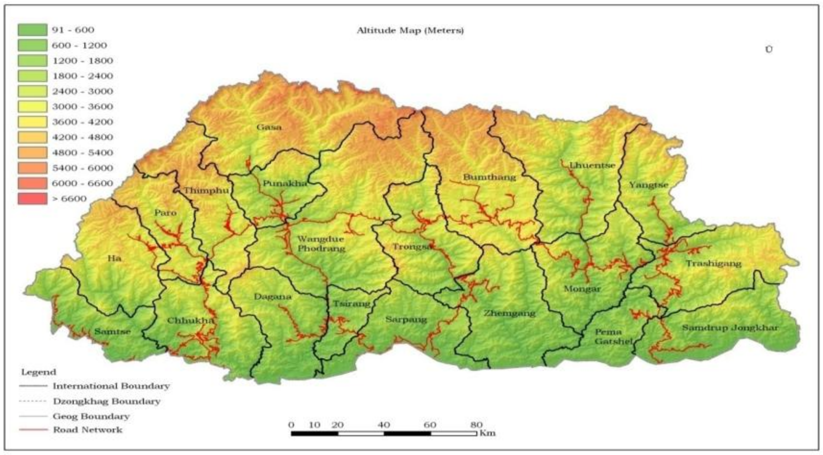

Fig. :1 Land covers Map of Bhutan (NSB, 2011

Table 1. Land cover and Land use Type

Land Category/Types of Vegetation and Land use	Land Type	Total Area	Area (Percent)
	Forest (Total) 70.5	27,052.90	70.5
	Blue Pine Forest	783.5	2
	Broadleaf Forest	16,850.20	
	Broadleaf with Conifer Forest	348.4	0.9
	Chir Pine Forest	1,137.20	3
Forest Areas	Fir Forest	1,804.40	4.7
	Mixed Conifer Forest	6,129.20	16
	Agricultural (Total)	1,125.50	2.9
	Wetland	319.1	0.8
	Dryland	682.5	1.8
	Citrus Orchard	54.9	0.1
	Apple Orchard	20.8	0.1
	Arecanut Plantation	12	0
Agriculture Areas	Cardamom Plantation	36	0.1
	Other Horticulture	0.2	0
	Bare Areas (Total)	1,229.50	3.2

Land Category/Types of Vegetation and Land use	Land Type	Total Area	Area (Percent)
Bare Areas	Bare Soils	0.3	0
	Rock Outcrops	996.6	2.6
	Scree	232.7	0.6
Degraded Areas	Degraded Areas (Total)	206.5	0.5
	Gullies	0.1	0
	Landslides	86.5	0.2
	Moraine Deposits	119.9	0.3
Marshy Areas	Marshy Areas	3.2	0
Meadows (Pasture)	Meadows	1,575.50	4.1
Shrubs	Shrubs	4,005.30	10.4
Snow Cover	Snow Cover	2,854.40	7.4
Water Bodies	Water Bodies (Total)	276.5	0.7
	Lakes	46	0.1
	Reservoirs	2.9	0
	Rivers	227.6	0.6
Built up Areas (Settlements)	Built up Areas	61.6	0.2
Non-Built up Areas (waste dump sites, mines, stone quarries and other extraction sites)	Non-Built up Areas	3.3	0
Total		38,394	100

Source: NSB, 2011

Area and Production Status of Maize Crop

Maize is a major food crop and is cultivated in 20 Dzongkhags, although the extent of cultivation varies among and within the Dzongkhags. It ranks first in terms of area cultivated among the food crops. About 69% of the Bhutanese households grow maize and maize contributed 46% to the food basket in 2010. Maize cultivation ranges from less than 300 m asl to nearly up to 2800 masl. Maize is especially important in the Eastern Districts where about 45% of production originates. The remaining production is spread almost evenly among the warmer districts in the rest of the country (East-Central, West-Central and Western regions). Maize is largely a subsistence crop with all produce consumed largely at home. Maize is mostly consumed in the form of *kharang*(grits). Other main uses of maize are as *Tengma*, (fried and flattened local snack), maize flour, pop corn and roasted and boiled ears. Some amount goes into making A*ara* (alcohol) (Table 2). Domestic maize used as feed is very insignificant. Maize used in the urban areas, by WFP for school meal program and for feed is mostly imported because of small volume of surplus available for sale which is widely scattered within the maize production areas.

The maize production environment in the country is broadly categorized into three zones based on the altitude. The three production zones are, Sub-tropical maize production zone I (<1200 masl) or low altitudes; Sub-tropical maize production zone II (1200 -1800 m asl) or mid altitudes; and the Highland maize production zone (>1800 m asl).The main crop is planted in February and harvested in August while the second crop is sown in early September and harvested in December. It is estimated that second crop of maize covers about 15% of the total maize area in the country (RNRRC 1996-97).

Table 2. Estimated Allocation of Maize for Different Uses at the Household Level in Rural Areas

Uses	Percentage Allocation
Seeds	3
Home consumption	80
Gifts/Animal Feed	11
Sales	6

Source: Maize Impact Assessment Survey, 2005 and Maize Commodity Chain Survey 2006

Different types of maize is cultivated in the country which includes with a variety of coloured kernels that are white, deep yellow, light yellow, orange and black that are either dent, semi dent or flint. Except for one improved maize variety Shafangma Ashom (S03TLYQ AB05) released in 2012 which is a Quality Protein Maize (QPM), all other maize varieties cultivated in the country are normal type. Popcorn is very popular and is mainly cultivated for its popping quality. Baby corn is cultivated in relatively smaller scale in Peri urban areas. Most of the varieties cultivated can be categorized as full season varieties with long maturity period with the exception of a very few short duration varieties that are used for double cropping and those used in the rice-maize rotation. The local varieties are recognizable by their distinctive morphological traits especially the tall height and small and compact tassel. Such land races are genetically diverse although detailed studies are lacking. Farmers give different names to varieties that show adaptation to micro-niches, soil types, sowing time, nutritive value and other properties. NBC has so far collected and documented a total of 105 land races from 15 districts. Districts showing high diversity include

Pemagatshel, Samdrupjongkhar, Lhuentse, Monggar, Trashigang and Trongsa (NBC, 2008). Although maize is cultivated in other districts like Dagana, Wangdue, Punakha and Haa, NBC is yet to record varieties from there. The area and production of maize in the country is presented in Figure1.

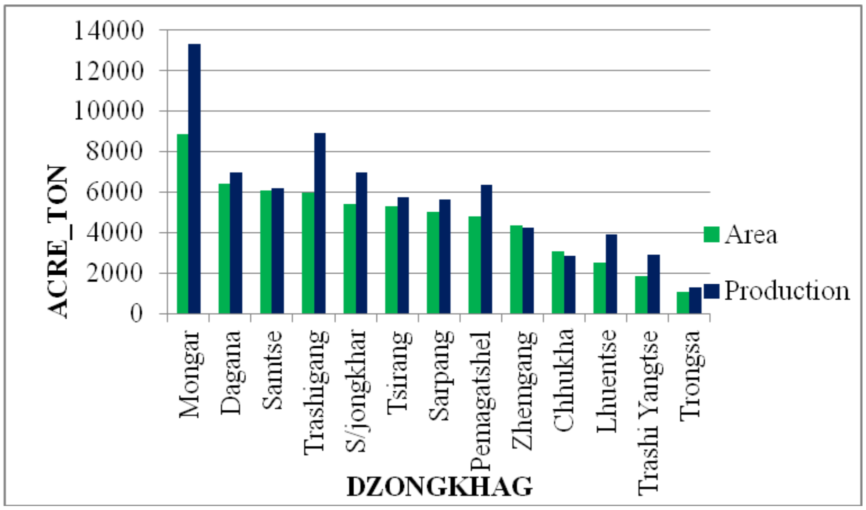

Fig. 2: Area and production of maize in Bhutan, 2011 – 2015 (BSB, 2015)

Table 3. Area, Production and Yield of Maize

Year	Harvested area (acres)		Production (MT)		Yield (Mt/acre)	
	Normal season	Spring season	Normal season	Spring season	Normal season	Spring season
2011	68975	NA	77985		1.10	NA
2012	63488	NA	73402		1.15	NA
2013	58338	NA	75715		1.29	NA
2014	58938	293	77244	468.8	1.31	1.60
2015	56805	5133	83,714	3239	1.47	1.80
2016	56609	666	82,035	1200	1.44	1.80
2017	NA	1000	NA	1800	NA	1.80

Source: BSB, 2017

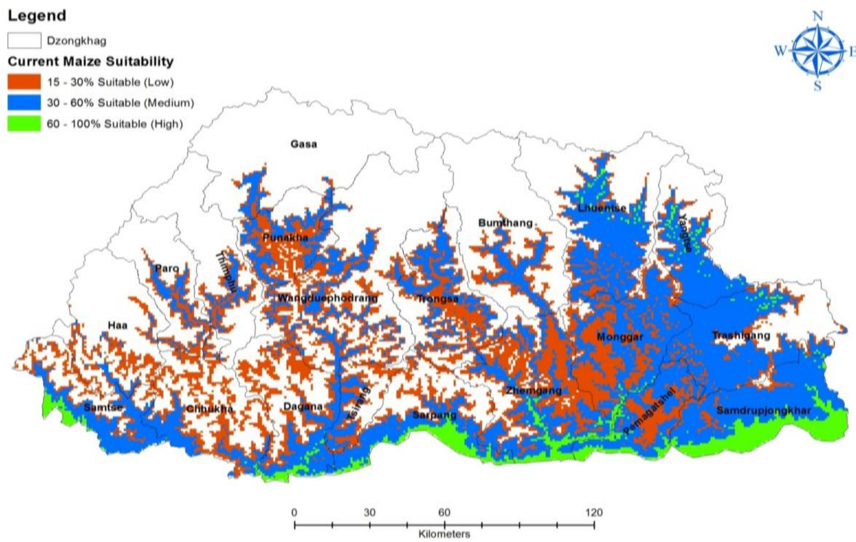

Fig. 3: Climate Suitability Map for Bhutan

Genesis of Maize Improvement Program in Bhutan

The present National Maize Commodity Program of the Department of Agriculture initially started in 1989 as the National Maize Improvement Program (NMIP). The NMIP was based at the erstwhile Agriculture Research Center in Khangma which is in Eastern Bhutan. With the relocation of the Agriculture Research Center from Khangma to Wengkhar in Mongar Dzogkhag (district) in 2004, the overall coordination and responsibility of the National Maize Program has been entrusted to the Agriculture Research and Development Center (ARDC), Wengkhar. The DoA has four (ARDCs) which are directly under the Agriculture Research and Extension Division (ARED) of the DoA. Among the four research and development centers ARDC-Wengkhar has been entrusted with the national mandate to coordinate the National Maize Commodity Program. As the institutional home for the National Maize Commodity Program, RDC Wengkhar is responsible for coordination, planning and implementation of the maize research and development activities in the country. The maize research and development activities are coordinated from ARDC-Wengkhar and are implement through other regional research and developments centers in collaboration with the Dzongkhags' Extension Services.The National Maize Commodity Program has broad-based objectives of developing production technologies and relevant information for the maize-based farming systems. The fundamental responsibility of the National Maize Commodity Program is to coordinate and implement maize research and development programs for the five year development plans. It is also responsible to develop and implement maize research and development aimed towards increasing the production ultimately contributing to the nation goal of household's food security. More specific objectives of the maize commodity program are:

- Overall coordination of the national maize commodity program.
- Formulation of plans and strategies for the maize commodity program.
- Introduce, adapt and select suitable high yielding varieties for the different maize production ecosystem in the country.
- Develop improved crop production and management technologies through adequate adaptation of new management technologies and the refinement of existing technologies.
- Conserve, improve and rehabilitate the local varieties through participatory involvement of the farmers.
- Develop appropriate post harvest technologies for reducing crop losses and value addition to diversify the utilization of maize and maize products.
- Basic seed production and maintenance of the released varieties.
- Develop and package the identified technologies for dissemination to the farmers in various forms such as technical recommendations, production manuals and leaflets.
- Generate reliable information to support the planning and formulation of development strategies for the maize commodity as a whole.

Since its inception, the primary focus and thrust of the maize commodity program has been on the adaptation of suitable technologies for sustaining maize production. Research has been initiated on three broad themes which include varietal improvement, production management and seed production technology.

Maize Production Technology, Post-harvest Handling, Value Addition and other Improved Technologies for Research and Development

Maize Production Technologies

- High Yielding Open Pollinated Varieties –Two GLS and TLB (Turcicum Leaf Blight) tolerant varieties have been released in 2012 for high altitude maize growing areas. One extra early variety has also been identified. The most popular variety Yangtsipa can be further promoted in new areas and for double cropping.

- Hybrid Varieties- The Maize program has evaluated both company and public sector hybrid which are ready for wider promotion.
- Quality Protein Maize – One QPM variety which is tolerant to GLS and TLB Shafangma Ashom has been released.

Post-harvest and handling

At present about 20% of the production is estimated as post-harvest losses. The ambient storage technology developed by the NPHC n needs to be scale up.

Value Addition

The quality of *Tengma* has been improved with the introduction of *Tengma* making machine. It has also reduced the drudgery involved. Further, in order to diversify the use of maize for food, product development was initiated since 2006 and various products (mainly value addition to *Tengma*) have been developed (Figure 2). The women farmers' groups are trained in product development and currently two groups are actively involved in producing different products on small scale. They also participate in events like agriculture exhibition/fair to show case the products.

In general the understanding and knowledge on maize processing in Bhutan is reported to be poor and at times products obtained after maize processing is used inappropriately (Singh, 2014). The short term TA on maize processing, value addition and product diversification has come up with recommendations and it's expected to overhaul the concept of maize processing in the country whereby the quality of the existing products *(Kharang & Tengma)* would be improved while new products will be developed to diversify the use of maize for food purpose. Maize processing and product diversification will be one of the major focus in the 11th five year plan (Wangchuk and Katwal, 2013).

Seed Production Technologies

- The maize program has put in place a national seed production scheme.
- The seed production and variety maintenance manual is in place.
- The on farm seed production model CBSP is ready for scaling up.

Potential scaling up of Proven Technologies for Bhutan

Spring Maize Production

The national maize program has successfully evaluated the hybrid technology. It has been proven that the net returns from the cultivation of hybrids by far outweigh the returns from normal crop. The national program has also evaluated many climate resilient hybrids which are ready for release and dissemination. To enhance the production of maize the promotion of spring crop with hybrid technology should be scaled up in the suitable areas.

Community Based Seed Production

Majority of the Bhutanese maize farmers grow different open pollinated varieties. Almost every maize farmer uses the recycled seeds from their farms for planting in the next season. Farmer's traditional or informal seed system is poorly organized and unscientific resulting in the deterioration and contamination of seed quality (Katwal, et al., 2015). Maize farmers are highly constrained by the inconsistent supply and access to good quality seeds. The formal public seed sector lack adequate resources to produce and supply good quality seeds. To address this issues the concept of "Community Based Seed Production"(CBSP) model was evaluated and adapted initiated by the National Maize Program to address the seed degeneration and rapid seed production of GLS tolerant maize varieties**.** The CBSP model was first tested in two sites in 2011 and slowly expanded to nine more locations in the subsequent years. It has been prove successful and is ready for scaling up.

The CBSP model was emulated from the successful demonstrations of its advantages to small holder hill maize farmers in Nepal by the Hill Maize Research Project (HMRP). According to Gadal, et al 2011, the CBSP approach has been proven to be highly successful and applicable for production and supply of quality maize seeds for small holder farmers in hilly areas of Nepal. In Bhutan, the concept and model of CBSP was introduced through the collaboration between the Bhutanese maize, HMRP and CIMMYT.

Promotion of Gray Leaf Sport and Turcicum Leaf Blight Tolerant Maize Varieties

Since 2006, the occurrence of two diseases the Gray Leaf Spot (GLS) and Turcicum Leaf Blight (TLB) has severely affected maize production in the Subtropical Zone I and II. The maize research program has evaluated and released two GLS and TLB tolerant varieties. Frontline demonstration and seed replacement of the GLS affected maize farmers in severely affected geogs have to be vigorously pursued. In the subtropical maize production Zone I, improved white flint maize varieties will be demonstrated.

Quality Protein Maize (QPM) Varieties

Bhutanese farmers are not aware of the nutritional value of QPM and therefore they have to be informed and educated on QPM. QPM was first developed by CIMMYT scientist. QPM looks and tastes like normal maize. QPM may yield as much or more and show equal or superior tolerance to pest and disease than the normal maize. The biggest advantage of QPM is that it contains nearly twice the amount of two important amino acids- Lysine and Tryptophan which are essential for synthesis of protein in humans and mono-gastric animals like pigs and poultry. It is considered to be more nutritive as it contains more balanced amino acid as compared to normal maize. It has already been proven through research that QPM can help reduce protein deficiencies especially in young children. It has also been proven that pigs and poultry raised on QPM based feeds gain weight faster and produce more as compared to those raised on normal maize-based feeds. The maize program has released one QPM variety namely S03TLYQAB05 introduced from CIMMYT Colombia.

Key Policy Input for Improvement of Proven Technology of Maize in Bhutan

Maize has been given a national commodity program status at the national level because of its primary role in household food security. Being a national commodity it has also been given an institutional home at RDC Wengkhar for the national level planning. The key policy inputs that will help to improve and disseminate the proven maize technologies sin Bhutan are:

- Support and recognition of maize research for adaption of improved technologies and generation of information for enhancing the development of the maize commodity.
- Policy support for commercialization of maize through contract farming so that the desired economy of scale could be generated to meet the demand of the maize using enterprises in the country. This will contribute towards reducing the current maize import from India. Maize has mainly remained as a subsistence commodity but it has a very huge scope for commercialization. The policy input for the development Maize-based enterprise through Public-Private Partnership (PPP model) help in enhancing production and marketing of maize. The support to private entrepreneurs for product development and diversification will also help in farmer’s income generation.
- Improve the marketing of maize through group marketing and other means to capture the institutional markets.

- Mechanization of maize processing using a suitable milling facility for diversification of products to encourage consumption and marketing of maize. The maize commodity analysis highlighted that there is a shortage of labor in the rural areas. At the same time, the processing of maize into Kharang is done at home consuming huge amounts of labor.

Challenges and Way Forward for Maize Research and Development in Bhutan

There are five distinct emerging trends for the maize industry in Bhutan. The challenges and opportunities for maize commodity thus hinges on these emerging trends:

i. **Decreasing maize acreage:** The decrease is largely due to legislation on *tsheri* (slash and burn) cultivation and decrease in shifting cultivation; crop displacement by more profitable crops like cardamom, vegetables and fruits crops and severe crop damage by wild animals that discourage farmers to cultivate maize.

ii. **Increase in overall maize production:** The increase is mostly attributed to increased yields from the adoption improved maize varieties, good quality seed and hybrid technology.

iii. **Declining consumption of maize as a staple:** The consumption of maize as a staple is on the decline due to the ability and access of the consumers to afford rice and the preference for rice.

iv. **Increase crop losses from natural calamities:** Attribute to Climate Change the frequency of extreme events like windstorm, flash floods, drought, heat and epidemic incidence of new pest and disease is affecting the crop.

v. **Increasing demand for maize from In-country maize based enterprise:** The demand for maize from in the country maize using enterprises such as the Karma Feed and Army Welfare Project is rapidly increasing. The feed based enterprise like Karma Feed alone has an annual demand of 12 MT.

Way Forward for Maize Research and Development

Research

Crop Improvement - Develop and promote disease tolerant, high yielding varieties including, QPM and hybrids. The ongoing crop improvement will focus on the following key areas in the 12th FYP:

- Identification and adaptation of drought and heat tolerant maize varieties

- Identify short duration drought tolerant/escape varieties for double cropping system
- Research on different types of corn to identify suitable types for processing and product diversification

Upscale research on post-harvest and processing with focus to minimize post-harvest losses for maize production zone I and II: Post harvest losses (20%) continues to be one of the main constraints in maize production Zone I and II. The main season of maize harvest coincides with the monsoon season and post-harvest damages through incidences of ear rots cause's harmful mycotoxins and afaltoxins. Minimizing post-harvest losses will entail selection of varieties with good husk cover, good keeping quality and less susceptible to damage by storage pest. Finally good storage facility at the household level will be vital.

Improved storage structures of maize: Develop and promote improved storage technologies at household and community levels. The main interventions that are ongoing at present are the distribution of grain storage community silos, household grain storage bins and the improved stores designed by the National Post Harvest Center (NPHC). Difficulty to store maize grains is more of a concern in the subtropical maize production Zone I due to the high humidity and storage pests. The selections of suitable varieties with good husk cover, grain texture, adequate drying and suitable storage facilities need to be designed to reduce post-harvest losses. The improved store designed by NPHC will be promoted in collaboration with the Dzongkhags.

Soil fertility and nutrient management technologies: Develop and disseminate integrated soil nutrient management technologies (including cropping patterns). It is perceived that maize farmers use substantial quantity of inorganic fertilizer, there is no reliable information. The only data available on fertilizer use on maize is from the Maize Impact Assessment study. Thereafter, the fertilizer recommendations should be updated based on available soil test data using cost benefit analysis. There is still a need to advocate the time and dose of fertilizer application to promote the optimal use of inorganic fertilizers through training, demonstration, and press and electronic media.

Identify and promote IPM technologies for major pest and diseases: Under the leadership of the National Plant Protection Center (NPPC), Integrated Pest management technologies for major pests needs to be developed and demonstrated to the farmers. The focus of the IPM will be on the following diseases, insects and weeds.

Table 4: Common Diseases of Maize

No	Diseases	Insects	Weeds
1	All types of Ear rots Especially • Aspergillus ear rots caused by *Aspergillusflavus*	Stem borer Armyworms	*i. Persicarianepalensis* *ii. Persicariaruncinata* *i. Fagopyrumdibotrys*
2	Fusuraium and gibberella ear rots caused by • *Fusuraiumgraminearum (syn. F. roseum)* • *Fusariumverticillioides (syn.Fmoniliforme)* Charcoal ear rot	Different storage pest – Grain Weevils Grain Moths	
3	Head Smut • Caused by *Sphacelothecareiliana*	Corn Leaf aphids for second season maize	
4	Stalk Rot		

Development

i. Commercialization of Maize through hybrids in maize production Zone I through contract farming and PPP model
ii. Promotion of Community Based Seed Production for improving the quality and quantity of maize seed.
iii. Put in place as sustainable marketing mechanism through PPP model
iv. Development and Promotion of maize based enterprise
v. Support and promote initiatives on maize product development and processing
vi. Promotion of QPM maize
vii. Promotion of extra early varieties for green cobs for kitchen garden in non-traditional pockets
viii. Promotion of popcorn varieties
ix. Introduction of grain/ fodder maize in non-traditional areas

Conclusion

Maize is cultivated by over 36,000 households for food and income. The two major cereals produced in the country are rice and maize. Maize has a larger area under cultivation as compared to rice and is also produced in larger quantities. The maize value chain shows that it is a subsistence commodity with as much as 94% being retained at home for consumption. Besides the maize grain, maize Stover has multiple uses in our mixed farming system, from fodder to bedding material for cattle and ultimately contributing to organic manure. Thus, the food security role of maize cannot be understated. However, the trend is changing and with higher urbanization and higher incomes, preference for rice is increasing. Thus, overtime, the importance of maize as a staple is likely to decrease. However, the demand for industrial use is increasing. Maize is a pro-poor commodity and is an important staple. Maize has an industrial value and can be developed into a potential cash crop for the farmers if it can be produced in adequate quantities. The investment on maize commodity program in the 12th FYP should attempt to increase production with the scope to generate enough volume that can sustain maize using enterprises. This will enhance the income of the farmers.

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Scaling-up of Proven Technology for Maize Improvement through Participatory Approach in India

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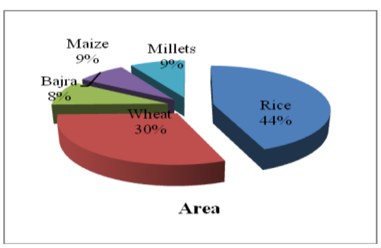
Introduction

The human population is expected to exceed 9 billion by 2050 (FAO, 2009). The availability of arable land is projected to drop to 0.8 ha per person by 2050 from availability of 2.5 ha per person in 1961. Fresh water needs to be increased to 64 billion m^3 every year, however, the availability of water is depleting. Vagaries of climate change are being felt everywhere. The impact of climate change on agricultural production is projected to be most prominent in the tropics and subtropics. South Asia is projected to be particularly vulnerable for multiple stresses due to low adaptive capacity (IPCC, 2007; ADB, 2009; Rodell et al., 2009; Niyogi et al., 2010). Thus, the challenge before agriculture is to feed this ever increasing population under changing climate and depleting availability of arable land and water (Rakshit et al., 2014). This can be achieved through higher crop yields per unit area rather than increasing the area under crops (Foulkes et al., 2011) and growing the crops that can adapt well to biotic and abiotic stresses limiting crop yields (Rakshit et al., 2014). Directly and indirectly cereal crops, *viz*., wheat, rice and maize account for approximately 50% of human food calories (Tweeten and Thompson, 2008). Among these top cereals, water requirement of maize is lowest (500 mm) as compared to that of rice (2100 mm) and wheat (650 mm).

Maize is the most versatile crop which is used as food, feed, fodder and in recent past as source of bio-fuel. It has wide adaptability. Worldwide it is being cultivated in over 170 countries representing an area of 185 million ha with a productivity of 5.62 t/ha (FAOSTAT 2017). Out of world maize production of 1037 million MT, SAARC countries comprising of Bangladesh, Bhutan, India, Nepal, Sri Lanka, Afghanistan, the Maldives and Pakistan represent 3.2% with a productivity of 3.8 t/ha. Among SAARC countries India represents the highest area (78.9%) followed by Pakistan (9.7%), Nepal (7.9%), Bangladesh (2.6%) and Sri Lanka (0.6%) but the highest productivity of 6.9 t/ha is reported in Bangladesh followed by Pakistan (4.3 t/ha), Sri Lanka (3.4 t/ha), Bhutan (3.0 t/ha), India and Nepal (2.5 t/ha). During the decade covering 2005 and 2014, maize area and productivity in SAARC countries has increased at an annual compound growth rate (ACGR) of 2.2% and 5.2% per annum, respectively. The impressive progress of maize in SAARC countries is a result of increased demand in poultry and other feed industry rather than increase in demand as food. Maize R&D efforts in some of the SAARC countries are several decades old while in some like in Bangladesh, maize cultivation is more of recent introduction. Since these countries are of close proximities, the challenges like biotic or abiotic stresses are relatively similar. The need for technological interventions may also have resemblances. This paper talks about the perspective of maize research in India with relevance to SAARC as a whole.

Agricultural Land Use

In India, the agriculture and allied sectors like forestry, livestock, poultry, fisheries and others account for over 13% of the gross domestic product (GDP). Over last several years, the economic contribution of agriculture to India's GDP is towards declining trend. However, India remains an agriculture dependent country where 58% of its population is directly dependent on agriculture. The total geographical area of the country is 328.7 million ha of which 141.4 million ha is net cropped area with cropping intensity of 142%. The net irrigated area of the country is 68.1 million ha which is 48.2% of net cultivated area. Over couple of years, the agriculture growth rate is hovering around 4%. In the year 2016-17, India produced little over 272 million MT food grains. Among cereal grains rice represent 44% of the gross cultivated area followed by wheat (30%), maize (9%), bajra (8%) and other millets (Fig. 1). Rice and wheat constitute 44% and 39% of cereal production, respectively, while maize represents little over 9% of cereal production.



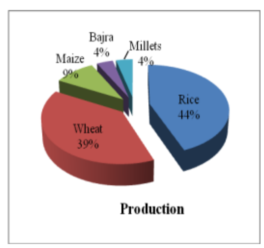


Fig. 1: Share of different cereal crops in Indian total cereal area and production

Source of data: http://eands.dacnet.nic.in/APY_96_To_06.htm

Area and Production Status of Maize Crop

In 1950-51, total maize produced in India was around 1.73 million MT, which was doubled to 3.46 million MT by 1958-59 on account of 35% increase in area and 48% in yield (Yadav et al., 2015). During the period of 1949-60 the annual increment in maize area was 109 thousand ha, while the productivity enhanced by 24.7 kg/ha/year (Fig. 2). In the 1960s the corresponding figures were 168 thousand ha/year and 7.4 kg/ha/year. The maize area during 1970s and 1980s was almost stagnant, while yield increment in 1980s turned significant at 29 kg/ha/year. This figure further increased to 37kg/ha/year in 1990s, which reached to its peak at over 46 kg/ha/year in the next decade (2000-10). Current yield increment is over 10 kg/ha/year (2011-17). With some slow down in area increase during 1980-90, the area under maize cultivation has also increased substantially and reached to historical maximum growth rate at over 200 thousand ha per year during first decade of this millennium. Currently maize area is increasing @ 70 thousand ha annually. The current five yearly average area under maize is 8.9 million ha and production is 23.0 million MT.

Maize in India is grown across the country (except for Kerala) in all the three seasons, i.e. winter or *rabi* (in Bihar and Peninsular India), rainy season or *kharif* across the country (except Goa and Kerala) and summer in Punjab, Haryana and western Uttar Pradesh. The major maize growing states are Karnataka (14.8%), Maharashtra (10.9%), Madhya Pradesh (10.8%), undivided Andhra Pradesh (10.4%), Rajasthan (10.6%), Uttar Pradesh (8.3%), Bihar (7.9%), Gujarat (5.0%) and Tamil Nadu (3.6%), accounting for nearly 80% of the total maize area of the country. However, productivity of maize in many of these states like in Rajasthan (1.6 t/ha) and Gujarat (1.6 t/ha) are quite low, while that in Uttar Pradesh (1.7 t/ha), Madhya Pradesh (1.9 t/ha) and Maharashtra (2.3 t/ha) are below the national average of 2.6 t/ha. In last five years, among all cereals, maize has recorded highest Compound Annual Growth Rate (CAGR) of 0.68% in yield and 0.73% in production.

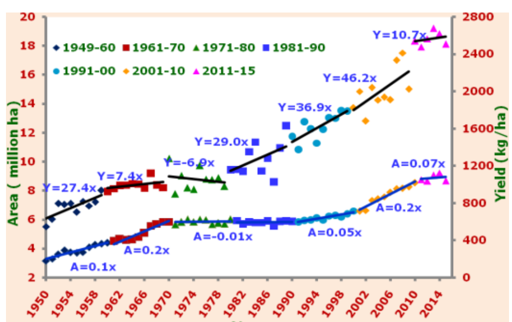


Fig. 2: Decadal change in maize area (A) and yield (y) in India
Source: Directorate of Economics and Statistics, Government of India.

Current production of maize in India is around 24 million MT, of which roughly 59% is used as feed, 17% for industrial purposes, around 10%

for export, 10% as food and 4% for other purposes including seed (Fig. 3).

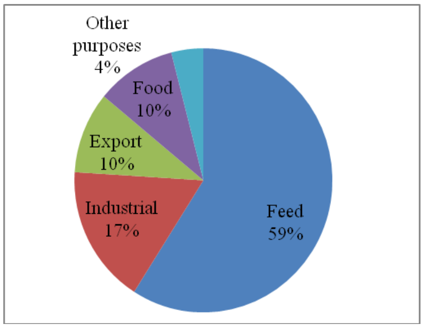


Fig. 3: Current usage pattern of maize

Source: Kumar et al., 2013

Demand for Feed and Fodder: In poultry production 60-70% cost is incurred on feed and maize is the principal ingredient used as the main source of calories and crude fibre. In India, the annual demand of maize is expected to increase by 5-9% mainly due to poultry industry alone. Maize, without anti-nutritional factors like HCN or oxalates, is a very good source of fodder than sorghum and pearl millet. Dry/stay green maize stover after harvest can be used as fodder. Besides maize stalk of some specialty corns, mainly sweet corn, baby corn and maize for green ears is a good source of green fodder and silage.

Demand for Industrial Uses: Corn starch is processed through wet or dry milling. Products of wet milling are corn oil, corn steep, liquor, gluten etc. The average recoveries of corn products during wet milling are: starch 60-62%, gluten 8-9%, germ 6-7% and husk 22-24%. The gluten is used in poultry feed, while germ goes for corn oil production. Maize starch is used extensively in pharmaceutical industry. Besides these maize starch is utilized extensively in fermentation industry to produce beer and distilled wines, antibiotics, enzymes, fuel alcohol, chemicals etc. The bi-products of starch industry may be used as food and non-food. Food uses like sweetener (corn syrups) is used in bakery and confectionary products. Non-food uses of corn syrups are several like bodying agents in inks, shoe polish, textile finishes, adhesive formulations, pharmaceuticals, in tanning leather and as humectants in tobacco industry. Dextrose derived from maize starch is a major component of candies, chewing gums, gum confections, hard candy formulations etc. Sorbitol, another derivation from maize starch is used in the production of synthetic vitamin C, high fructose corn syrups and is used in a variety of ways such as confections, baked goods, table syrups, sweet beverages etc. Corn oil has high content of unsaturated fatty acids and is recognized as a dietary component for reducing blood cholesterol levels. The present consumption of maize in starch and industrial products at the level of 4.25 million MT is expected to rise to 15 million MT in coming 5 years.

Demand for Food: The proportion of maize for human food is likely to reduce. However, with increased population the demand of maize for food purpose will increase from 1.3 to 4.0 million MT in coming years. The increased demand will be more for specialty corn products like sweet corn, baby corn, popcorn, corn for green ears and Quality Protein Maize (QPM) products. QPM offers the scope to address dual need of food and nutritional security. Sweet corn and baby corn have high phyto-nutrition profile comprising of dietary fibre, vitamins and antioxidants in addition to minerals in moderate proportion. They are one of the richest sources of phosphorus. Baby corn is high in folic acid, B_6 vitamins, riboflavin and vitamin C. It also contains zeaxanthin and lutein which help to prevent cataract. The demand for sweet corn and baby corn is rapidly increasing in urban areas of the country. It has potential for export to international market.

Demand for export: With increased production of maize, the country has been able to meet its domestic need. Besides meeting the domestic need India has been exporting maize for last fifteen years (since 2003). Maize export reached its peak in 2013-14, however, is dropping since then (Fig. 4). India mainly exports maize to South East Asian Countries like Indonesia, Vietnam, Malaysia, etc.

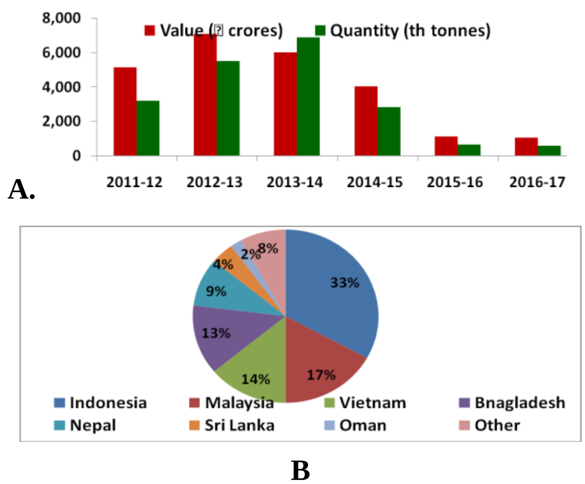


Fig. 4: Maize export over years (A) and main export destinations from India (B)
(Source: Based on the data of APEDA website, http://agriexchange.apeda.gov.in/indexp/genReport_combined.aspx)

Genesis of Maize Improvement Program in India

In 1947 when India got independence, the per capita food availability in India was 407 g/day. Realizing the importance of agriculture to meet the food requirement, the Government of India decided to revamp the agricultural research. Accordingly the Indian Council of Agricultural Research (ICAR) constituted a high powered committee in 1953 under the chairmanship of Dr. EJ Wellhausen from Mexico and Dr. UJ Grant from Columbia as member. Considering the fact that maize had highest productivity among all cereals and has wide adaptability to diverse environments, the committee gave emphasis on maize in its report submitted in 1954. Based on the recommendation of the Committee, with support of the Rockefeller Foundation, ICAR established the All India Coordinated Maize Breeding Project in 1957 with its founder Coordinator, Dr. RW Cummings. This is the first project of its kind. In the initial years, the project was limited to the disciplines of Breeding and Agronomy with 17 centres in major maize growing states of the country. It was realized that the pace of breeding programme for north Indian centers was hindered due to low temperature during winter (*rabi*) season. To address the needs of such centers a Winter Nursery was established at Hyderabad in 1962 for off-season advancement of breeding materials. Hyderabad was identified as most suitable place due to its neutral environment allowing growing of crops across the year. With the support of PL480 of the USA in 1963, the mandate of the project was enhanced by including the disciplines of Entomology and Pathology and renamed as All India Coordinated Maize Improvement Project (AICMIP).

Development and release of widely adapted high yielding cultivars resistant to major diseases and insect pests through extensive multidisciplinary and multi-location testing was the objective of AICMIP. It also aimed at shorten time of adaptation, exchange of ideas on germplasm and avoiding duplication of breeding efforts. Through a coordinated effort, hot spots for major diseases and insect pests were identified and sick plots and insect rearing facilities (stem borer) were developed to screen the breeding materials. However, lack of infrastructure facilities was the major hindrance to increase number of testing locations. In 1960-61 there was only one agriculture university in India *i.e.* Govind Ballav Pant University of Agriculture & Technology (GBPUAT) at Pantnagar. The need to establish universities in other states were realized and State Agricultural Universities started being established. Already identified maize research farms gradually became part of the university research farm and the testing locations turned out to be center under AICMIP.

Under AICMIP, the entire country was divided into five agro-climatic zones with one major center in each zone, *viz.*, Srinagar in Zone I, Delhi in Zone II, Pantnagar in Zone III, Hyderabad in Zone IV and Dholi in Zone V. These centers were further strengthened by including all the disciplines to generate breeding materials by supplying diverse maize germplasm procured from different countries. Remaining centres in the zone were used for testing purpose. Subsequently, all the centres started development of own breeding materials. The AICMIP was elevated to the Directorate of Maize Research in 1994 and to the Indian Institute of Maize Research in 2015. Currently the basic, strategic and applied research for overall improvement of maize in India is being coordinated across 34 regular centres including two ICAR institutes *viz.,* Indian Agricultural Research Institute (IARI) and Vivekananda Parvatiya Krishi Anusandhan Sansthan (VPKAS). In addition over 30 voluntary centres are also involved in testing new hybrids.

Initiatives between 1960 and 1970: Prior to inception of coordinated project on maize in 1957 isolated efforts were being made at various places. As product of such efforts the first hybrid, Punjab Maize Hybrid No. 1 was released in 1956. Under AICMIP the major emphasis was laid on introduction of exotic germplasm mainly from North and South America and Caribbean region. This was carried out with the support of the Rockefeller Foundation. Simultaneously, systematic collection and characterization of indigenous germplasm was also taken up. During this period, the activities were taken up under the aegis of the Plant Introduction Division of IARI, New Delhi where storage of large collections was an issue. Hence, a strategy was followed to bulk similar collections, which were named as Indian Maize Collection bulks (IMC bulks). A total of 110 such IMC bulks were maintained under the project. Using the introduced Corn Belt inbred lines, first set of four double cross hybrids, *viz*., Ganga 1, Ganga 101, Ranjit and Deccan were released for commercial cultivation in 1961. In addition many lines were procured from South America and other Caribbean region. Spread of hybrids demanded infrastructural facilities to produce and sell seeds of the hybrids. To address these requirements the National Seeds Corporation (NSC) was established in 1963. In the initial years of NSC, both seed production and certification was carried out by them. However, shortly after that, the certification process was delinked to the Ministry of Agriculture, Government of India. Private seed players were also allowed to sell truthfully labeled (TL) seeds to ensure seeds reach the farmers. Two progressive farmer organizations, *viz.*, Massina Beej at Samastipur, Bihar and Tonnage Club at Dahod, Gujarat took up production of these hybrids (Singh, 2017). However, with lack of knowledge about yield advantages of these hybrids marketing of the hybrids faced a big challenge. The Massina Beej contributed significantly towards spread of high yielding cultivars of maize, particularly *rabi* maize in Bihar. Three small seed processing plants were established, one each at IARI, New Delhi; Massina at Samastipur, Bihar; and Dahod, Gujarat with support from Rockefeller Foundation. Sole objective of these plants was to produce and process seeds. Terai Development Corporation (TDC) was established in 1965 at Pantnagar and later 13 more State Seed Corporations came into existence in the country. In the history of Indian agriculture this decade remained important when the country waded through the curse of food insufficiency to self sufficiency through green revolution. In the process, the priority of seed production by the National and State Seed Corporations was shifted to rice and wheat rather focusing on maize, which needed more focused attention. This gave a setback to maize hybrid programme of the country. Considering the challenge of hybrid seed production, option of double top cross (DTC) hybrids with easier seed production was also considered and a set of DTC hybrids, *viz.*, Hi-starch and Ganga Safed 2, Ganga 5 etc. were released from 1969 onwards. During this period, the Rockefeller Foundation established Inter Asian Corn Improvement Programme (IACP) with its Head Quarter at Suwan in Bangkok. Under this, the improved pools and populations were developed to upgrade and exchange material between the Asian countries. In 1966, International Maize and Wheat Improvement Centre (CIMMYT) was established in Mexico and large number of exotic germplasms developed by Rockefeller Foundation and CIMMYT were introduced to India in the form of pools and populations.

Realizing the demand for seeds in the country and limitations of the hybrid seed production, the Indian maize improvement programme took a conscious decision to focus on raising the level of base germplasm with dual objectives: (i) to release synthetic/composite varieties as cultivars for commercial cultivation where farmers could use seeds from his own harvest up to 3-4 years, and (ii) to improve the population base enabling extraction of more productive inbred lines towards hybrid development. The full-sibs developed by CIMMYT in different populations were sent to India for evaluation and utilization. Systematic crossing of exotic pools and populations with native germplasm led to release six composite varieties, *viz.*, Vijay, Kisan, Amber, Vikram, Sona and Jawahar in 1966. Vijay became popular not only in India but also in the adjoining countries, when it was released in Pakistan under name of J1 and in Nepal as Rampur Yellow (Dhillon et al., 2006). These composites did not cover large areas due to their long duration. With 85% of area under rainfed early duration locals were preferred. During this period two mutants with high lysine and tryptophan, *Opaque-2* (O_2) and high methionine *flory-2* (fl_2), were introduced in the year 1965-66 opening new branch of focus on quality protein maize (QPM). The composite varieties and DTC hybrids became popular among farmers, and productivity improved significantly during 1958-1970, leading to doubling of production reaching 7.49 million MT. This was achieved mainly due to increased yield (57.5%) and partly due to increase in area (37.0%). In the mean time, Pre-Breeding activities were initiated by screening germplasm for yield, resistance to diseases and insects pests through International Progeny Testing Trials (IPTT), Experimental Variety Trial (EVT) and Elite Variety Trials (ELVT), which were grown in different agro-ecologies. Trap nurseries were regularly used at the testing locations by growing both susceptible and resistant checks of the targeted disease and/or insect pests. Sick plots were established at the hot spots for mass screening of germplasm. At later stage the trap nurseries were converted into Survey and Surveillance Nurseries (SSN) for disease and pest monitoring purpose.

Initiatives between 1971 and 2000: The initiatives during the previous era on QPM fruited into release of three QPM varieties, *viz*., Shakti, Rattan and Protina with soft endosperm in 1971. However, these varieties could not become popular in spite of having quality traits due to loose packing of starch in endosperm, dull texture, vulnerability to diseases and store grain pests. Later, a hard endosperm QPM variety, Shakti 1 was release in 1997 taking advantage of modifiers. However, this variety also could not become popular due to lower productivity than normal maize. Large number of composites developed and released during this period (for details refer to Dhillon et al., 2006).

Simultaneously, ICAR continued to strengthen the maize hybrid development programme to develop hybrids specifically suitable for winter and spring seasons. Open ended heterotic pools in different maturity groups were developed by ascertaining the heterotic patterns of the inbreds, pools, populations and varieties using parents of the best single cross hybrid as testers. Efforts were made to extract inbred lines from these pools, which were expected to be heterotic to each other. Simultaneously introgression of temperate germplasm into the tropical materials was also carried out, particularly in Ludhiana, Hyderabad and Almora centres. The level of introgression was monitored so that the germplasm could adapt to the varied agro-ecological conditions of the country experiencing severe to mild cold conditions. Some centres focused on extraction of inbreds through pedigree breeding from the best single crosses, which remained largely a short term strategy. The project introduced large number of inbred lines, developed by CIMMYT and used directly to develop hybrids after acclimatization. Screening of inbreds developed or received from CIMMYT was carried out for biotic and abiotic stresses under artificial inoculation infestation and in high plant population densities, to identify resistant lines which can withstand high plant population densities in hybrid combinations.

The public bred hybrids (Deccan 105 and Ganga 11) and composites (Sartaj) whose seeds were produced and marketed by both public and private sector agencies dominated the marker till 1980. Introduction of National Seed Policy in 1988 was a significant policy decision taken by Government of India. It allowed the private sector seed companies to produce and sell seeds of public bred hybrids, in original name. Further, private sector was allowed to have access to the parental lines and to the composites, which were earlier accessed by public sector institutes only. This changed the scenario significantly. Some seed companies started their own R&D to develop hybrids and produce certified and truthfully labeled seeds. This helped to meet requirement of quality seed in the country. Further private bred hybrids/varieties were allowed to be tested under the coordinated trials.

The first single cross hybrid, 'Paras' was released by Punjab Agricultural University in 1996. During the initial period of hybrid breeding, the private sector was not enthused to develop and produce single crosses due to apprehension of pilferage of parental lines of the hybrids from seed production area. The single cross hybrids developed by the project having better productivity than DC or DTC hybrids attracted attention of 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 parental lines was provided. In the mean time, as obligation under WTO, Government of India enacted two important bills, *viz*., Protection of Plant Verities and Farmers' Rights Act (PPV&FRA), 2001 and Biodiversity Act, 2002. During the period production recorded up to 60% increase, while the area increased by 25%.

Two major international initiatives during the period influenced maize research in India. These are establishment of Tropical Asian Maize Network (TAMNET) in 1993 by the FAO Regular Programme in Bangkok and the Asian Maize Biotech Network (AMBIONET) in the year 1998. TAMNET was mandated to test and exchange hybrids developed in Asian Countries with an objective to find out hybrids and germplasm suitable in other Asian Countries. AMBIONET intended to support biotechnological researches in the region.

Initiatives post 2000: During this period, both QPM research and hybrid maize programme received major focus. Maize project scientists developed more than a dozen QPM maize single cross hybrids using hard endosperm QPM inbreds received from CIMMYT. Using marker assisted selection (MAS), the first QPM version of normal maize, Vivek QPM 9 was released in 2008. Recently, essentially derived QPM hybrids through MAS, *viz*., Pusa HM-8 Improved (AQH-8), Pusa HM-9 Improved (AQH-9) and Pusa HM-4 Improved (AQH-4) and improved QPM hybrid, Pusa Vivek QPM-9 Improved (APQH-9) with enhanced vitamin A content were released by IARI. Due to increase in demand for specialty corn, the specialty corn research also received impetus during the period which has led to development and release of several hybrids of specialty corn namely baby corn, sweet corn, and popcorn. Even though maize hybrid Prakash was being cultivated as baby corn but the first hybrid identified as baby corn, sweet corn and popcorn namely HM 4, HSC 1 and BPCH 1 and were released for commercial cultivation in 2005, 2010 and 2015, respectively. Recently, two more new hybrids namely FSCH 18, a sweet corn hybrid and DMRHP 1402, a popcorn hybrid were also released in 2016 and 2017, respectively for commercial cultivation. In addition, several sweet corn hybrids *viz.*, NSCH-12, Mishti, Candy (KSCH-333), Hy-brix 53 (ADVSW-2) and Hi-brix-39 (ADVSW-1) have been released from private sector as well to meet the increased demand for sweet corn.

The protection provided in the PPV&FR Act encouraged private sector to invest more to develop and market single cross hybrids and modified single cross hybrids. Major shift in breeding priorities beyond 2000 was more emphasis on single cross hybrids. Out of the 220 cultivars released between 2000 and 2017 only 42 (19.1%) are OPVs. Among released hybrids, numbers of public and private bred cultivars are 94 and 84, respectively. Medium to long duration cultivars continue to receive more prominence with 33.6% of the releases to be of late maturity, while 31.8% are of medium maturity. Early and extra early cultivars constitute 33.7% of total releases since 2000. There are substantial number of cultivars released by both private and public sector for all major maize growing states (Fig. 5).

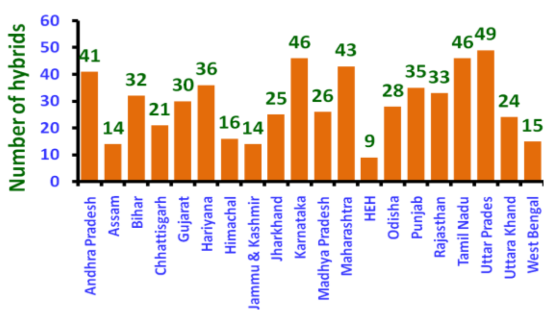


Fig. 5: Number of hybrids released for major maize growing states since 2000.
Source: IIMR, Unpublished data, 2017

Rough estimate suggests that around 65% of the maize area in India is covered under hybrids. In terms of single cross hybrids it is 22-25% of the maize area. Area under winter and spring maize in the country has also registered a steep growth of 270% during the period (Singh, 2017). Average productivity of winter maize is as high as 4.1 t/ha and some farmers are harvesting up to 11-12 t/ha with irrigation and high input condition. However, *kharif* maize dominates the maize scenario, out of which 80% or above is rainfed, which is the main reason for lower productivity of Indian maize programme.

Maize Production Technology, post-harvest handling, value addition and other improved technologies for research and development

Maize Production Technology

Better production technology for hybrids: The quantum jump in maize production has been achieved both through increase in area and yield gains. Yield gains in any crop are realized through both genetic gains and better crop management. While the traditional landraces were tall in nature and low yielder, the hybrids with different plant architecture call for different crop management. Efficient production technology has been developed in maize for various ecosystems. Agronomy being location specific, all centers of the project are involved in development of location specific agronomic practices to enhance productivity. Special emphasis be given to workout non-monetary output practices, such as, date of sowing, plant population, method of sowing and fertilizer application etc. Package of practices developed for each agro-ecology of the country, which pay rich dividend are to be propagated among maize farmers. Mix of inorganic and natural resources (manure, nitrogen fixing crops) is included in the package of practices for better yield.

For *kharif* irrigated crop, plant population of 74-80 thousand per ha found to be optimum. Nutrient management with 10 t/ha FYM, N-P-K @ 150:75:75 kg/ha proved to be remunerative. Similarly for rainfed *kharif* season crop, 66 thousand plant population and 10 t/ha FYM along with N-P-K of 120:40:40 kg/ha have been worked out. *Rabi* maize with 80-90 thousand plant population per ha and N-P-K @ 250:105:105 kg/ha reported to give the best return. However, extensive studies suggest site-specific nutrient management gives best results so far nutrient management is concerned. Contrary to traditional two-split application of N, 4-5-splits of N proved to be much more effective. In recent past organic maize is also gaining prominence. However, this found to be more remunerative under intercropping with legumes. Young seedlings, knee high stage (V_8), flowering (V_T) and grain filling (GF) are the most sensitive stages for water stress and hence irrigation should ensured at these stages. The application of crop residue @ 5 t/ha found effective for enhancing maize productivity under rainfed conditions.

Weed is a major production constraint particularly in *kharif* maize. Application of Tembotrione @ 120 ml a.i. per ha at 25 DAS along with application of Atrazine @ 1.0 kg a.i. per ha as pre-emergence herbicide found to be very effective. The tank-mix application of Atrazine (700 g a.i. per ha) + Pendimethalin (700 ml a.i. per ha) as pre-emergence found most effective for providing weed free conditions up to 25 days after sowing. Inter-cropping with vegetables (cabbage, cauliflowers, spinach), legumes (pigeonpea) etc. proved to be very effective to ensure higher and regular income to the farmers, better risk management and mitigating climate changes (Fig. 6). Intercropping of specialty corn with vegetables proved to be a boon, particularly in peri-urban ecologies.

Fig. 6: Intercropping of maize with cotton, cabbage and spinach
(Maize+Cotton at Chindwara (MP) in kharif season and Maize + vegetables at Delhi in winter season)

Resource Conservation Technology: Resource conservation technologies (RCT) offer an opportunity to plant full season maturity cultivars, reducing time between *kharif* harvest and sowing of *rabi* crop, reducing cost on fossil fuel, improving organic carbon, enhancing nutrient use efficiency, conserve moisture, to help to reduce pollution due to burning of fossil fuel and improve environmental safety. Traditionally farmers plough the land several times using tractors after harvest of *kharif* crop, which require 15-20 days for land preparation. This leads to loss of soil moisture and increasing the need of irrigation. Zero tillage (ZT) technology provides an opportunity to plant full season maize hybrids without the need of land preparation using specialized seeding machineries like zero-till raised bed planter and zero-till multi-crop planters having inverted T type furrow openers and integrated fertilizer drills.

ZT and crop residue incorporation in maize-based cropping system proved to be highly remunerative. Retention of residues and crop rotation practices in maize based cropping system arrests soil erosion, improve soil organic carbon content, soil health and ensures moisture conservation. Laser leveler alone can reduce irrigation water requirement by 20-30%. Site-specific nutrient management and placement of nutrients in root zone along with sowing by the zero till-cum-fertilizer seed drill further enhances the crop productivity and nutrient use efficiency. Maize system productivity of 11.3–12.9 t/ha with reduced water requirement by 40–65 ha-mm under ZT has been reported in maize (Parihar et al., 2016). It gives up to 31% higher net returns with lower production cost. RCT is gaining momentum in Indo-gangetic region and in peninsular India. Currently in the state of Andhra Pradesh and Tamil Nadu over 100 thousand ha maize is being cultivated under ZT. Maize bed planter and ferti-cum-seed planter are some of the implements most commonly being used under ZT. Drip irrigation under ZT is specifically recommended for spring maize for enhancing water productivity and minimizing irrigation water requirement (Fig. 7).

Fig. 7: Drip irrigation under zero tillage maize at Ludhiana

(Courtesy: Dr. M.L. Jat, BISA, Ludhiana)

Plant Protection Technology: Though chemical control measures against insect pests and diseases are established, eco-friendly control measures needs to be practiced. Incorporation of pest resistance in the released cultivars has remained in priorities since beginning. Biopesticides though is quite effective its extensive use in controlling maize pests is yet to be a matter of regular practice. So far specialty corns like sweet corn, baby corn and maize for green cobs are concerned there should be more judicious application of pesticides. Farmers earn more if specialty corns are produced organically than under chemical control.

Mechanization: Farm mechanization ensures timely operations, labour and natural resources, reducing cost of cultivation, increased per day productivity, quality produce, improved living standard, enhanced per manpower farm income, crop intensification, reduced labour drudgery among others. In India, land preparation and to some extent sowing are mechanized, while harvesting, and post-harvest handling is predominantly manual. In Tamil Nadu and other parts, Combined Harvester is being used by the farmers. To a large extent mechanical and power operated shelling machines are being used by farmers, particularly in peninsular India.

Post-harvest Handling: Post-harvest quality of maize is dependent on moisture at harvest, weather and storage conditions. Normally maize crop is harvested at 18-20% grain moisture level. The grain has to be stored at 12% moisture to protect them from store grain pests (rice weevil) and fungal infection (aflatoxin). About 5% losses are estimated during harvesting, shelling, winnowing, transportation and cleaning. However, availability of proper grain storage facility is rare in the country. As a result maize grains are damaged during storage. Up to 20% losses are reported at storage level. Sun drying, particularly during *kharif* season is difficult due to cloudy weather and high humidity. Hence, there is need to install dryers and metal silos and storage facilities at community level for safe storage of grain.

Secondary plant metabolites have been identified from different medicinal plants having ability to protect maize grains from rice weevil. For example, Tanacetene from the leaves of *Ixora coccinea* @ 0.0036 mg/cm^2 shows repellence activity. Similarly, *Ageratum conyzoides* leaf powder @ 2% w/w stored in High Density and Double layered polythene bags found to be quite effective. Further, 4 hrs Sun drying along with application of *Erythrina indica* leaf powder @ 2% w/w also proved to be effective. However, proper drying is very essential (PL Soujanya, personal communication). In India, though minimum support price (MSP) for maize is there and it is steadily increasing @7.9% CAGR and currently reached INR 1425 per quintal, hardly maize grains are purchased according to MSP. The whole maize market is operating in an informal manner where middlemen play a major role.

Value Addition: Maize grains are processed using three major processes, *viz*., dry milling, wet milling and alkali processing. The end products of these are being utilized as raw materials for the production of more than thousand products by small, medium and large enterprises. The products of dry milling are grits (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, and manufacture of glucose by direct hydrolysis etc. Series of maize based ready-to-cook (RTC) and ready-to-eat (RTE) products have been developed by the Rajedra Prasad Agricultural University, Dholi and University of Agricultural Sciences, Manyda. Maize-based vermicelli, crisp, noodles and papad developed by UAS, Mandya are being marketed in the brand name of ‘Maizy’ in the state of Karnataka.

Though food security has been largely achieved, nutritional security is far from accomplished. Macro and micro nutrient malnutrition is of common occurrence. In this context QPM offers a good solution to address the issue of nutritional security. Convenience foods and specialty products can be developed after the alkali processing from QPM. Such products have better digestibility and palatability with enhanced availability of niacin. RTE foods have been prepared from QPM which can meet the nutrition needs of various sections of the society.

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

Other improved technologies for research and development: The main challenge before current agricultural practices is that these are making soil hungry and thirsty due to decrease in soil biota like beneficial microbes, arthropods, anelids etc. Organic carbon in the soil is also decreasing. Degradation of soil and natural resources, contamination of ground water among others adversely affect total factor productivity. In this context the production technologies are to be developed in a bottom up approach taking the farmers' field conditions into consideration (Singh, 2017). There is a need for crop diversification and use of appropriate water savings technologies to conserve ground water. In this context maize play a pivotal role, particularly in rice-wheat ecosystem across Gangetic plain, which is becoming unsustainable over time.

With reduced water availability, upland *kharif* rice in the state of Odisha, Jharkhand and Madhya Pradesh is facing problem. Maize has potential in such areas. In the same context *rabi* rice can be replaced with maize in West Bengal, Karnataka, Andhra Pradesh and Tamil Nadu. In western India summer rice is strongly not recommended, where spring maize can be a potential replacement. With rising terminal temperature wheat is suffering in several states like Bihar, Madhya Pradesh, Jharkhand, Chhattisgarh, Rajasthan and Gujarat, opening up potential for maize. With changed rainfall *kharif* sorghum in central India suffers immensely due to grain mold, where *kharif* maize may be more acceptable. Soybean is a success story in Madhya Pradesh and Maharashtra. However, in recent past yellow vain mosaic virus (YMV) and rust are emerging as a new production constraint of soybean in this region. Untimely rain leads to lack of pod formation. Maize may be proved to be a viable alternative to soybean. Cotton in states of Maharashtra and Gujarat often face water stress where maize may be again a viable alternative as maize requires lesser water (500-800 mm) than cotton (700-1000 mm). Some new avenues are emerging in the context of changing climate, infrastructure facilities and economic opportunities. One such is *kharif* maize in flood prone areas of Bihar, Eastern Uttar Pradesh etc. Flood is of common occurrence from the middle of August, particularly in the eastern region of the country. Rain starts in this region by the beginning of June. Planting of maize can be enhanced taking advantage of the pre-monsoon shower and if speciality corns like sweet corn, baby corn and corn for green ears are taken harvesting of green cobs may be completed before the flood arrives. Further, after harvest of green cobs the green stalks can be used as fodder and/or silage making. Local entrepreneurs may take up baby corn and sweet corn for canning or making many value added products out of those (Fig. 8).

Fig. 8: Baby corn value added products: a. Candy, b. Dehydrated baby corn, c. Salted baby corn, d. Baby corn murabba, e. Baby corn juice, d. Baby corn in brine solution (Courtesy: ZARS, UAS, Mandya, Karnataka, India)

Potential Scaling-up of Proven Technologies for SAARC Countries

The main challenge in this context is to enhance productivity. For this a detailed action plan needs to be developed involving all stakeholder, *viz.*, planners, researchers, farmers, processors and traders in a Public-Private-Producer Partnership (PPPP) mode to address the issues in a holistic manner. A mechanism is to be evolved to continuously upgrade the knowledge of all stakeholders' right from researchers, technology agents, farmers etc. The challenge of increased productivity may be attained by following defined strategies as follows:

- Enhancing breeding efficiency

- Hybrid seed production
- Production and protection technologies
- Development of maize value chain
- Policy interventions

Strategies for Enhancing Breeding Efficiency

Strengthening the pre-breeding activity: To make the breeding efforts more relevant the research agenda should focus on development of the new hybrids responsive to the external inputs, which use nutrient and water more efficiently, having higher resistance to biotic and abiotic stresses, adapted to unfavourable areas and production systems, produce economic yield with higher nutritional value and desirable organolyptic properties. To attain these, desirable alleles for traits of economic importance like resistance/resilience to biotic and abiotic stresses need to be identified and deployed in cultivar development through pre-breeding. The breeding activities should be carried out in a bottom up approach taking the farmers' need in a particular agro-ecosystem into consideration.

Constitution of heterotic pools under various maturity groups is very important. However, off late emphasis towards this direction has been reduced. Available germplasm as well as exotic introductions are to be thoroughly screened for the traits of economic importance as well as heterotic relationship. Put lines into heterotic groups using parents of best single cross as testers for each maturity groups will greatly help the maize breeding efforts. This will further help to extract promising heterotic lines as well as effective recycling of lines. Information on germplasm gone in to each pool are to be maintained meticulously and brought out in every 2-3 years, to ensure that the material introgressed once are not reinfused in the pools and a balance of introgressed materials are maintained in each heterotic pool. The focus of breeding efforts should be towards development of single cross hybrids.

Genetic enhancement for stress tolerance: Adverse effect of climate change is being felt across crops including maize. To address these, climate resilient maize germplasm is to be developed by incorporating traits imparting tolerance to drought, water logging, high temperature etc. Simultaneous selections under combination of stresses should be the strategy to develop cultivars. Managed screening sites and standardized protocols to screen germplasm for combinations of stresses under controlled conditions suited for a target environment should be developed. Recent international collaborative initiative to develop unified screening against abiotic stresses through two separate projects, *viz*., Climate Resilient Maize for Asia (CRMA) and High Temperature

Tolerant Maize for Asia (HTMA) is worth mentioning. High throughput phenotyping coupled with high throughput genotyping opens up the opportunity to identify genomic regions contributing stress tolerance.

Use of frontier technologies for enhancing genetic gains: Advances made in breeding techniques like Doubled Haploid (DH), molecular marker-assisted breeding, high throughput precision phenotyping of traits of interest, decision-support systems/tools offer new opportunity for enhancing genetic gains and breeding efficiency. There is a need to integrate DH techniques and high throughput genotyping with conventional breeding progaramme to improve breeding efficiency. GWAS and genomic selection (GS) are yet to be deployed in regular maize breeding programme in India. Genetic engineering, RNA interference and CRISPER technique provide us new tools to engineer maize germplasm resistant to biotic and abiotic stresses in long run. Availability of an efficient regeneration and transformation tool among tropical germplasm is the need of the hour.

Adoption and development of genetically modified (GM) maize: GM maize is being cultivated in 60.6 million ha in 16 countries (ISAAA, 2016). The top five countries include the USA (30.1 million hectares), followed by Brazil (15.6), Argentina (4.7), South Africa (2.2), and Canada (1.5). In India some GM events from private sectors are under field trials but none of them have received permission for large scale cultivation. Research programme should be strengthened to develop GM maize able to control insect pests and diseases, and tolerate herbicides. However, in the process care should be taken to address biosafety issues effectively.

Strategies to Strengthen Hybrid Seed Production: It is established that SCHs perform better than OPVs in most of the given conditions. The challenge is to make hybrid seeds available at farmers' doorsteps. Though maize can be grown across the country, there is a need to identify suitable area and season for hybrid seed production, which can act as seed hub to support the seed need of the location. Currently major seed production hub for maize SCHs is Andhra Pradesh and parts of Telangana. However, this adds up to the total cost in terms of transportation charges besides ensuring seed availability at the right time. The regional seed hubs need to be supported with adequate seed processing facilities. This can be carried out in a PPPP mode. Necessary storage facilities in each region should be developed as contingency measures to manage maize crop in *kharif* for unforeseen situations. Crop insurance in case of disaster to cover loss caused by abiotic stresses should be ensured.

Seed production of single cross maize hybrid is to be taken up in a mission mode to bridge the productivity gaps. A rolling plan for seed production for at least 5 years should be prepared to out scale better SCHs suitable for a specific region. Such plan needs to be jointly decided by a committee of scientists, seed sector representatives and a group of progressive farmers. Private sector needs to be encouraged to invest more in R&D to develop SCHs specifically for *kharif* season. Currently in many states hybrid seeds are procured from private seed companies on the basis of tender. Later such seeds are distributed among farmers as subsidy. In this process often suitability of the hybrids in a given situation is not taken into consideration leading to failure of the crop. This practice needs to be discouraged. Regional/state demonstration with ruling hybrids in the market may be conducted and jointly visited by committee represented by maize scientists and farmers and best hybrids may be selected for the purpose of subsidized seed distribution. The benefit of subsidy should be extended to the best hybrid irrespective of notified or truthfully labeled (TL) developed by public or private sector.

Indian seed sector is well established among SAARC countries, and it has potential to grow beyond its domestic boundaries and capable to support SAARC countries. Enabling environment should be created to promote export of seed for better earning. Adequately trained human resources should be engaged for seed certification to ensure quality standard. Also, seed quality testing laboratory should be equipped for testing of transgenic seeds, QPM apart from normal seed.

Production and Protection Technologies: Agronomic recommendations need to be revisited towards sustainable intensification by adopting conservation agriculture for reducing cost on inputs, improving soil health, water and nutrient use efficiency towards improved production and farmers' income and reducing environmental foot print. Organic mulching, on farm soil and water management including micro irrigation where ever possible are to be practiced. In plant protection, priorities are to be given to control biotic stresses by emphasizing host plant resistance, IPM approaches and biological control methods. This will help to reduce loss of beneficial insects/soil biota, less pesticide in the food chain, reduced human health hazards and environment pollution, and improved farm income.

Development of Value Chain: While developing maize value chain, focus should be given towards improvement of efficiency, consumer preferences/demands, industrial supply and benefits to consumers. Processing of maize for value addition involving local women and youth should receive priorities. This can offer considerable off-farm job opportunity for better profitability to the farmers. Also, more wet milling industries are required to be established to meet demand for starch and its derivatives. Farmers should be sensitized about newly developed QPM SCHs and the advantages associated with QPM. Poultry feed producers also need to be educated on the superiority of QPM over normal maize. QPM should be procured and provided though public distribution system (PDS) in the states predominated by tribal and poor masses where maize is directly consumed as food to ensure nutritional security.

Key Policy Input for Improvement of Proven Technology of Maize Crop in South Asia

Maize R&D planning

- The R&D planning should be done involving all stakeholders including farmers, scientists, development agencies, private sector enterprises and policy makers ensuring a harmonized action plan.
- Focus should be demand driven after creating right production-consumption ecosystem.
- Frontier technologies like DH, MAS, GS, GWAS and CA should be integrated in the R&D strategies.

Prioritizing sustainable intensification practices

- Sensitization of farmers towards government policies towards doubling farmer's income and other policy initiatives to conserve natural resources. Flagship programmes of the government like PM Agricultural Insurance, PM Irrigation programme, RKVY, NFSM, NHM etc. though have been initiated, their fruits must reach the targeted group.
- Resource conserving maize based farming systems though showed its benefits, these need to be scaled up to ensure significant social, economic and environmental benefits.

Capacity building

- Periodic capacity building programmes for the grass root workers like technology agents, field officers and other functionaries with improved maize production and processing technologies should receive priorities.
- Local youths and women need to be empowered with business skills and to manage risks. Maize-based value chains are to be developed at village level in a PPPP mode through self help groups (SHGs), producer companies, farmers' cooperatives etc.
- Capacity building towards farm mechanization, storage and transport should also be encouraged in PPPP model.

- Creation of non-farm rural employment should be the priority rather making the farmers dependent on external agencies.

Out-scaling innovations

- The yield potential and realized yield gaps in maize can only be bridged up by disseminating the improved location-specific production technologies in a PPPP mode involving local agriculture graduates as paid technology and input agents.
- Investment on maize R&D is to be increased to upscale and out scale innovations. Developmental activities, particularly creation of infrastructural facilities like roads, cold chains, cleaning, grading, processing, storage, community drying etc. are essential to reduce storage losses and ensuring better bargaining power to the farmers.
- Contract farming by major processors will ensure better return to the farmers, which will encourage them to adopt better production technologies. An institutional mechanism needs to establish to arrange easy credits for the farmers and local entrepreneurs to out-scale proven technologies.

Maize farmers – market linkages

Marketing of farm produce is the key to encourage farmers towards a particular commodity. E-marketing using various portals developed by government and private entities like e-NAM (National Agricultural Market), StarAgri, ReMS etc. are to be popularized among both farmers and consumers using electronic and print media, as well as social networks.

- Organizing producer groups, SHGs, farmers' companies, contract farming, etc. will ensure better access to technology, quality inputs, business skills, capital investment, and credit facility helping the farmers to come out of the clutches of money lenders.
- Organized farmers may open outlets/shops at highway roadside or in nearby town/cities allowing better income to the farmers. Specialty corn products like frozen sweet corn, baby corn, roasted green ear, and packaged popcorn, readymade QPM dry milling products, feed *etc*. will provide more profit to the farmers.

Challenges and Way Forward for Maize Research and Development in South Asia

The productivity of *rabi*/spring maize (4.1 t/ha) is almost double that of *kharif* maize (2.3 t/ha). However, the *kharif* maize represents 82.3% of total maize area. To enhance maize production, the productivity of *kharif* maize needs to be increased substantially. About 75% *kharif* area is under rainfed condition, while *rabi* and spring maize is predominantly grown in favourable ecologies. With the increase in irrigation facility some irrigated *kharif* area is likely to be shifted to maize due to its comparative advantage in productivity than other *kharif* crops (Singh, 2017). However, tropical and sub-tropical environmental conditions during *kharif* season like shorter day length, early maturity, hot night temperature, poor quality sunshine, cloudy weather, various biotic and abiotic stresses *etc*. prevents realization of potential productivity during *kharif* season. Further, under climate change extreme weather events like uneven rainfall, drought, flooding, high temperature, high wind *etc*., also adversely affect particularly *kharif* maize productivity. Heat stress at flowering and grain filling stages in spring maize causes substantial yield losses.

Biotic stresses such as post flowering stalk rot (PFSR), leaf blights, banded leaf & sheath blight (BLSB), downy mildews (DM), ear rots (ER), borers, and weeds adversely affect maize productivity. Among insect pests, stem borer (*Chilo partellus* Swinhoe) is a common problem across year. Pink borer (*Sesamia inferens* Walker) is of major concern during *rabi* season, particularly in the southern peninsular region. Spring maize is gaining popularity in northern parts of the country, particularly in the states of Punjab, Haryana and western Uttar Pradesh. With this shoot fly (*Atherigona spp.*) is becoming a major problem, particularly when the crop is sown late.

Conclusion

The success story of maize in India and other SAARC countries over last two decades has remained phenomenal. The production has increased both due to significant increase in area as well as productivity. Genetic gain due to introduction of hybrids, more precisely single cross hybrids, and better crop management have contributed towards productivity enhancement. The drive behind the maize revolution in India and other SAARC countries is the demand of maize grain as feed, more particularly poultry feed. Though impressive progresses have been made a huge gap between potential and realized yield exists, which can be bridged only though up-scaling and out-scaling the proven technologies among the maize farmers. The maize R&D policy needs to follow a bottom-up approach with involvement of all stake holders. Changing climate has brought a new dimension to the whole maize R&D scenario. Still maize assumes better advantages than other cereals in addressing this challenge. India being strategically located with its long history of organized maize research may play an important role to lead the maize R&D in SAARC by sharing expertise, imparting trainings and acting as seed hub for the whole region. Government policies encouraging closer collaboration among SAARC countries will benefit not one country but all others as well.

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Scaling-up of Proven Technology for Maize Improvement through Participatory Approach in Nepal

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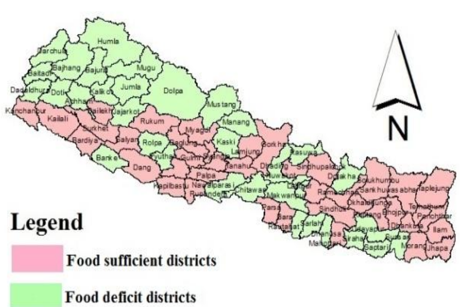
Introduction

Maize (Zea mays L.) is a monoecious plant having male and female flowers in different inflorescences of the same plant. It is world's second leading cereal crop after wheat. It has the C4 photosynthetic pathway which is more efficient than C3 pathway under high temperature and dry land condition. C4 plants are most productive in terms of food nutrients produced per unit area. It was the principal food plant of the Indians when Columbus arrived and, it is still the most important cereal crop in many countries. Maize is one of the oldest cultivated crops. How long maize has been grown and where it came from are still matters of investigation.

The National Maize Research Program (NMRP) is a commodity research program of Nepal Agricultural Research Council (NARC) that seeks to improve the well-being of present and future generation of people by developing consumer preferred high yielding maize technologies. Maize contributes about



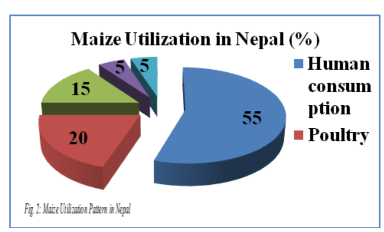


Fig. 1: District Wise Edible Production in Nepal, 2015/0163

Source: MoAD, 2017

3.15% in National Gross Domestic Products (GDP) and 9.5% in Agricultural GDP. It occupies 42.82% area of the total food crops (rice, maize, wheat, millet, barley and buckwheat) in the hills and 26.97% in the country, and contributes 45.42% and 25.90% of the total cereal production in the hills and country, respectively. Similarly, contribution of maize to total edible production (5355232 tons) is 26.82% and to the total requirement (5426631 tons) is 26.47%. Mountain and hilly regions are food deficit and only Terai has surplus edible production. Total edible balance is 71399 tons in negative direction in the country. Out of 75 districts 35 districts have insufficient edible balance (Fig. 1).

About two-third of Agriculture GDP comes from the crops sub-sector with the remainder from the livestock sub-sector (MoAD, 2012). The inflation rate on food is around 10% and 38% of less than 5 years old children are suffering from stunting even though almost 60% income is utilized only for food (CBS, 2013). The current situation of Nepalese Agriculture is in a low development stage, leads to food trade deficit. Maize is second staple food crop of Nepal and the principal food, feed, fodder, fuel crop and source of energy in the hills. Maize is an important crop for food, feed and nutritional security of the country. A large portion of maize production goes for human consumption (Fig. 2). Consumption of maize is 44.5 kg per capita per year by a Nepalese consumer. Nepali consumes 122 gm of maize that supplies 426 kcal energy per capita per day (FAO, 2009). Likewise, maize requirement for poultry feed is about 1,095,000 tons per annam and only 35.25% of total requirement is fulfilled from Nepalese production and rest is imported from India (Dawadi, 2014).

Agricultural Land Use

According to MoAD (2015) the total area of Nepal is 14,718,100 ha and land use statistics has been presented in Table 1. Paddy ranks the first in area and productivity followed by maize, wheat and millet, respectively (Table 2).

Table 1: Land Use Statistics (‘000 ha) of Nepal

Land Use	Area, ha
Agricultural land cultivated	3091
Agricultural land uncultivated	1030
Forest including shrubs 1560)	5828
Grass land and pasture	1766
Water	383
Others	2620

Source: MoAD, 2015

Table 2: Area and Productivity of Cereals in Nepal

Crop	Area, ha	Area, %	Productivity, kg/ha
Paddy	1362908	41.22	3154
Maize	891583	26.97	2503
Wheat	745823	22.56	2329
Millet	266799	8.07	1133
Barley	28361	0.86	1157
Buckwheat	10842	0.33	1074

Source: MoAD, 2017

In addition to cereals, cash crops, pulses, fruits, vegetables, tea, coffee and spice crops are also grown in Nepal and are exportable commodities (Table 3). Due to climatic diversity, various crops are grown in Nepal within a short distance of altitude.

Table 3: Area (ha) and Productivity (kg/ha) of various Crops in Nepal

Crop	Area (ha)	Productivity (kg/ha)
Cash Crops *	507544	
Pulses**	327321	1083
Fruits	110586	8830
Vegetable	280807	13992
Tea	20747	1148.17
Coffee	2618	203
Spice crops***	56148	

Source: MoAD, 2017

* *Oilseed, Potato, Tobacco, Sugarcane, Jute and Cotton*

** *Lentil, Chickpea, Pigeon Pea, Black Gram, Grass Pea, Horse Gram, Soybean and Others*

*** *Cardamom, Ginger, Garlic, Turmeric and Chilli*

Area and Production Status of Maize Crop

Maize is less attended crop compared to rice and wheat even during the green revolution period despite maize is being the second most important crop after rice in Nepal.

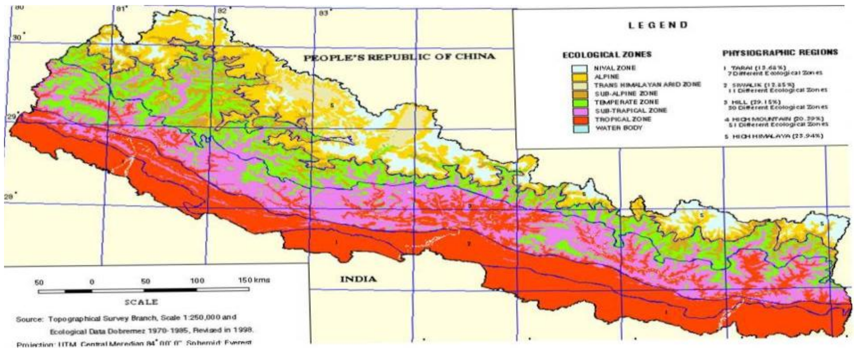


Fig. 3: Maize Production Environments in Nepal

Source: Topographical Survey Branch and Ecological Data Dobremez, 1998

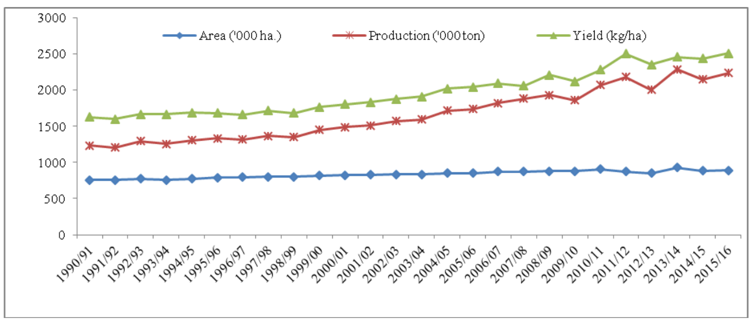


Fig. 4: Trend of Maize Area (ha), Production (ton) and Productivity (kg/ha) in Nepal (1990/091-2015/016)

Source: MoAD, 2017

Therefore, maize area, production and productivity declined sharply during the Green revolution. Area, production and productivity of maize increased only after 1985. The growth rate of maize productivity was encouraging in early years of post green revolution era that was mainly because of cultivation of winter and spring maize, introduction and release of high yielding varieties and wider dissemination of seed to the farmers.

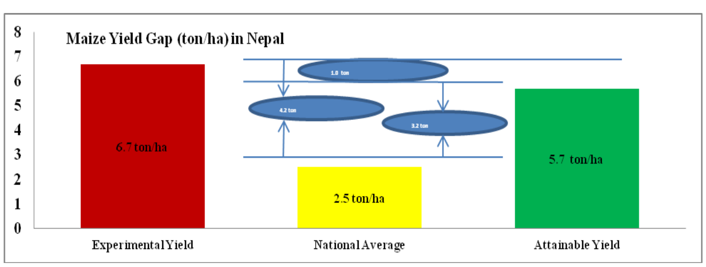


Fig. 5: Maize Yield Gap in Nepal

Source: Koirala, 2014a

Table 4: Maize Area (ha), Production (ton) and Productivity (kg/ha) by Seed Type

Ecological Belt	Seed Type				
	Improved	% Area	Local	% Area	Total
MOUNTAIN					
Area	71857	92	6248	8	78105 *(8.76%)*
Production	151617		10418		162035 *(7.26%)*
Yield	2110		1667		2075
Yld. Increment over Local (%)	26.57				
HILLS					
Area	605812	94	38669	6	644481 *(72.29%)*
Production	1520588		65497		1586085 *(71.08%)*
Yield	2510		1694		2461
Yld. Increment over Local (%)	48.18				
TERAI					
Area	163927	97	5070	3	168997 *(18.95%)*
Production	471618		11779		483397 *(21.66%)*
Yield	2791		2323		2725
Yld. Increment over Local (%)	20.15				
NEPAL					
Area	841596	92	49987	8	891583
Production	2143824		87693		2231517
Yield	2547		1754		2503
Yld. Increment over Local (%)	45.21				

Source: MoAD, 2017

Maize is the second most important crop in terms of area (891583 ha) and production (2231517 ton) with productivity of 2503 kg/ha in Nepal (MoAD, 2017). It is widely grown in all three agro-ecozones: Terai and Inner Terai (below 900 msl), mid hills (900-1800 msl) and high hills (above 1800 msl) (Fig. 3). Out of the total maize area in the country 8.76, 72.29 and 18.95% belongs to mountain, hills and Terai with productivity of 2075, 2461 and 2725 kg/ha, respectively. The area, production and productivity of maize are in increasing trend (Fig. 4). The average productivity of improved maize is 2547 kg/ha as compared to local maize (1754 kg/ha) which is 45.21% higher than local (Table 4). Seed replacement rate (SRR) of maize is quite low (9.5%). Nearly 5% area is covered by hybrids, 90% by improved open-pollinated varieties (OPVs) and 5% by landraces (SQCC, 2013).

There is a big maize yield gap of OPVs in Nepal. The experimental yield when research conducted in stations is 6.7 ton/ha, when trials conducted in farmers' field led by researchers, the grain yield is 5.7 ton/ha whereas the national average is only 2.5 ton/ha (Fig. 5). A number of reports have indicated that there is still scope for improving maize production and productivity through increasing SRR of improved OPVs and hybrids, and developing other cost effective production technologies that are suited to our farmers' need.

Genesis of Maize Improvement in Nepal

The National Maize Research Program (NMRP), Rampur is located about 10 km west of Bharatpur, the district headquarter of Chitwan, in inner Terai region of Nepal with collaborative testing sites across the country in 1972. The geographical location is 27^{o}40' N latitude, 84^{o}19' E longitude at an altitude of 228 meters from the mean sea level. It has humid and subtropical climate with cool winter (2-3^{0}C) and hot summer (43^{0}C). The annual rainfall is over 1500 mm with monsoon (>75% of rainfall) period from mid-June to mid-September. The soil is slightly acidic, light textured and sandy loam. The program operates its research activities on four major areas: maize varietal development (maize breeding and seed production), crop management (agronomy, soil science and agri-engineering), crop protection (plant pathology and entomology) and outreach.

- The first open-pollinated yellow maize varieties "Rampur Yellow and Khumal Yellow" were released in 1965. Science then, systematic maize research and development initiated.
- 29 OPVs (27 normal and two QPM) have been released so far.
- Research on hybrid maize was initiated in 1980s. The first single cross hybrid "Gaurav" was released in 2003. This hybrid was not successful due to non-synchronization nature of parental lines. Five single cross hybrids have been released and two heat stress resilient hybrids namely Rampur Hybrid-8 and Rampur hybrid-10 have been registered in 2017 for commercial cultivation (product of a USAID funded "Heat Stress Tolerant Maize for South Asia" Project).

- 55 Multinational Company Hybrids (MCHs) have been registered to fulfil the immediate needs of farmers till 2017.
- Seven OPVs are denotified.

Maize Production Technology, Post-Harvest Handling, Value Addition and other Improved Technologies for Research and Development

Variety Development and Seed Production

Open-pollinated Varieties (OPVs): Improved OPVs are the main technologies for increasing production and productivity of maize in Nepal. Research findings proved that 15-20% yield increment can be attributed through replacement of local varieties by improved ones at the same level of management. Moreover, in inaccessible areas of mountains and hills still the OPVs will remain very important in the coming years.

Full Season (Long Duration) Varieties: Full season OPVs are released for all ecological belts of Nepal. These varieties are mainly grown in rain fed condition during summer season. Out of 24 released long duration varieties 7 are already denotified (Table 7) and 17 are still in cultivation, and a few is in pipeline (Table 5).

Fig. 6: Manakamana-6

Source and Location: Koirala et al., 2010; RARS, Lumle

Table 5: Full Season (Long Duration) Open-pollinated Maize Varieties Developed and Released by National System

SN	Full Season Variety	Released Year	Source	Yield, ton/ha	Days to Maturity	Recommended Domain
1	Poshilo Makai-2	2017	CIMMYT	4.6	120-Summer 160-Winter	Terai and Inner Terai up to 800 Meter during Winter; Mid-hills (800-1800 Meter) during Summer Season
2	Manakamana-7	2017	CIMMYT	6.5	158	Mid-hills (700-1600 Meter) during Summer Season
3	Rampur-4	2017	CIMMYT	5.4	170	Terai and Inner Terai up to 700 Meter
4	Resunga Composite	2014	Nepal	5.2	127	Hills of Mid and Western Region (700-1400 Meter)
5	Manakamana-6	2010	Nepal	5.34	140-145	Mid-hills (East of Karnali River)
6	Manakamana-5	2010	Nepal	5.27	140-145	
7	Poshilo Makai-1	2008	CIMMYT	5.3	145-155	Below 1600 Meter , East to West Mid-hills
8	Manakamana-4	2008	CIMMYT	5.3	117	Below 1600 Meter , East to West Mid-hills
9	Shitala	2006	CIMMYT	6.08	130-135	Hills
10	Deuti	2006	CIMMYT	5.7	130-135	Mid-hills
11	Manakamana-3	2002	CIMMYT	5.5	142	Mid-hills of Eastern, Central and Western Development Region (1000-1700 Meter)
12	Ganesh-1	1997	Nepal	5.0	175	High-hills
13	Rampur-2	1989	Nepal	4.0	105-110	Terai, Inner Terai, Besi and Tar
14	Ganesh-2	1989	Nepal	3.5	150-180	High-hills, During Winter in Terai and Inner Terai
15	Manakamana-1	1987	Nepal	4.0	120-130	Mid-hills, During Winter in Terai and Inner Terai
16	Rampur Composite	1975	Thailand	4.4	110-115	Mid-hills, Terai, Inner Terai and Besi
17	Khumal Pahenlo	1965	India	4.9	120-130	Mid-hills

Source: Joshi et al., 2017; MoAD, 2017 (2074.07.30 BS)

Early Maturing (Short Duration) Varieties: Early maturing (short duration) varieties are recommended in those areas where farmers grow more than two crops in a year. They are mainly spring season maize where farmers grow paddy after maize. These varieties are suitable for baby corn purpose and roasted green cobs as well, and can be grown in all seasons where temperature is not a limiting factor. Five early maturing varieties have been released till date (Table 6).

Fig. 7: Arun-2

Source and Location: Koirala et al., 2015a; NMRP Rampur

Fig. 8: Arun 3

Source and Location: Koirala et al., 2015a; NMRP Rampur

Fig. 9: Arun-4

Source and Location: Koirala et al., 2015a; NMRP Rampur

Fig. 10: Arun-6

Source and Location: Koirala et al., 2015a; NMRP Rampur

Table 6: Early Maturing (Short Duration) Open-pollinated Maize Varieties Developed and Released by National System

SN	Early Variety	Released Year	Source	Yield, ton/ha	Days to Maturity	Recommended Domain
1	Arun-6	2015	CIMMYT	3.5	90	Mid-western to Eastern Terai and Inner Terai, Mid-hills (Winter and Summer)
2	Arun-4	2015	Nepal	4.2	113-115	Mid-western to Eastern Terai and Inner Terai, Mid-hills (Winter and Summer)
3	Arun-3	2015	Nepal	3.9	100	Mid-western to Eastern Terai and Inner Terai, Mid-hills (Winter and Summer)
4	Arun-1	1995	Nepal	4.0	90-100	Western Terai and Mid-hills
5	Arun-2	1981	CIMMYT	2.2	80-90	Terai and Mid-hills

Source: Joshi et al., 2017

Denotified OPVs

Table 7. Denitrified Maize Varieties and Reasons for Denotification

SN	Variety	Released Year	Reason for Denotification
1	Rampur-1	1995	Denotified- Recommended for Western Terai, inner Terai and mid-hills, it is white grain maize variety and presently, there is virtually no demand for white grained maize in Terai, inner Terai and thus it is preserved in cold store for future uses.
2	Makalu-2	1989	Denotified- Recommended for high hills like Lumle and Pakhribas areas as well as Mid-hills, Two yellow grained maize variety Makalu-2 and Ganesh-2 were released in 1989 for hills. Nevertheless, Ganesh-2 became popular in the maize millet cropping system as compare to Makalu-2.

SN	Variety	Released Year	Reason for Denotification
3	Janaki	1978	Denotified- Janaki was recommended for Terai and Sarlahi Seto for Eastern Terai and Inner Terai. These two varieties were of white grain type. Since past few years, the market demand for white grain in Terai and Inner Terai is very limited. Therefore, the highly desirable traits of these varieties were incorporated in Manakamana-1 and Manakamana-3 which are highly popular among farmers.
4	Sarlahi Seto	1975	
5	Hetauda Composit e	1972	Denotified- Recommended for Mid-hills, Inner Terai, Besi and Tar Areas. Farmers got better option and choice through Rampur composite, Manakamana-1 and Rampur-2 in place of Hetauda Composite for .yield and other desirable characters (Plant and Ear Height, Lodging Resistant, Disease Resistance etc.).
6	Kakani Pahenlo	1966	Denotified- Recommended for high hills, desirable genes of this variety are incorporated on Manakamana-2 and Manakamana-6
7	Rampur Pahenlo	1965	Denotified- This variety was downy mildew (DM) disease susceptible and thus replaced by Rampur composite which is DM tolerant/resistant.

Source: Joshi et al., 2017

Nutritious Maize: South Asia's share of the global number of chronically under-nourished people has increased from 31% in 1990–1992 to 35% in 2011–2013 (FAO, 2013). South Asia has also more than halved (129 to 60 per thousand live births) under-five mortality rate between 1990 and 2012 (UNICEF, 2014). In the 1960s, protein deficiency was seen one of the principal factors contributing to malnutrition in developing countries. Since then, energy and protein requirements for humans have been reappraised twice and attention has turned from protein deficiency per se to the more general problem of protein-energy malnutrition caused by low food intake. To allow children between one and two years old to grow at twice the normal growth rate, the energy requirement must be raised 4%, but the protein requirement must be increased about 30% (FAO/WHO/UNU, 1985).

Quality Protein Maize (QPM): Protein and protein-energy deficient malnutrition, nutritional anaemia, free radical damage, growth retardation, diminished resistance etc. are the common identified problems especially in vulnerable groups (developing foetuses, infants, children, elderly population, women before and during pregnancy and while breastfeeding, and patients under stress, resource poor, small scale, marginalized and socially disadvantaged groups) in developing countries. Likewise, babies who subsist on maize face terrible deficiency of protein during developmental stages. Therefore, it is essential to supply quality protein to each and every individual with special emphasis on vulnerable groups. Countries where majority of the population depends on maize for health and upkeep of their body, to ensure nutritional security for them, the staple must be improved to provide quality protein. Fortunately, maize is an important cereal crop commonly used as staple food, which has been improved (QPM) for quality protein answering the above mentioned problems. QPM with better balanced amino acid composition can successfully be utilized to achieve food security by enhancing maize production, to assure nutritional security by meeting the protein needs, and to play a big role in poverty reduction program by developing maize based entrepreneurship.

Sluggish growth in maize production and productivity, and future threat of maize imports, food and nutritional insecurity and its consequences, lack of varietal selection options of farmers' referred QPM varieties, big yield gap between attainable and farmers' harvest, lack of information about new technologies, lack of quality seeds of farmers' preferred varieties, costlier quality seed and high cost of maize production sustaining poverty are the key problems which farmers are facing in Nepal. Protein from livestock sources in the Nepalese diet is about 13% (recommended 30%) (NPC, 2011). Nutritionists emphasize unsustainable medical approaches to solve malnutrition problems by using supplements and fortified foods (Welch, 2005). QPM has specific features of having high content of lysine and tryptophan. Advantage of QPM is that monogastric animals utilize carotenoids, the precursors of vitamin A better than normal maize (Bosque and Bressani, 1987). The lysine in maize is the first and tryptophan the second limiting amino acid. Potassium, zinc and oil content may show an increase in QPM over the normal counterpart (Kies et a., 1965 and Vasal, 2001). QPM is nutritionally risk-free. Children can meet 90% of their protein requirements by eating 175 grams of QPM (Viteriet al., 1972 and CIMMYT, 2000). The biological value of common-maize protein is equal to about 40% of the biological value of milk protein, whereas the biological value of QPM protein is about 90% of total the milk protein (Bressani, 1990). For instance, each gram of QPM gives the same amount of usable protein as at least two grams of normal maize. By extension, therefore makes maize farming at least twice as efficient in terms of protein production. It is just like a low-volume and high-value in real sense. Normal maize replaced with QPM ensures better income to the farmers and higher nutrition to the consumers. QPM not only significantly improves protein-deficiency malnutrition but also prevents pellagra. It is reported that in Colombia, Peru, and Ghana, malnourished children were brought back to normal health on a diet containing only QPM as the source of protein (CIMMYT, 2000; Cordova and Listman, 2002).

In Nepal, most of the farmers reported that QPMs are easy for grinding in local grinder. They added that pudding (prepared from grits) from QPM varieties namely Poshilo Makai 1 and S01SIWQ-3 is very soft and preferred by elderly population and children, and different items prepared from QPM are tastier than from normal maize. One kg maize was grind in local milling structure called Janto and grit recovery percentage was calculated based on weight of grit and flour. Highest grit recovery of 71.8% was recorded in QPM variety Poshilo Makai-2 followed by Poshilo Makai-1 (69.7%). Other tested QPM varieties have grit recovery percentage less than that of farmers' local (68.2%). Based on organoleptic test, different varieties were found suitable for various specific purposes (Table 8).

Fig. 11: Poshilo Makai-2

Source and Location: Koirala, 2013; Jayamangala, Chitwan

Table 8: Ranking of QPM Varieties by Stakeholders Based on Grit Recovery and Organoleptic Test, Combined over Locations (Gorkha, Arghakhanchi and Dang District)

Variety	% Grit Recovery	% Flour	Average Rank of the Varieties (I-VI)*			
			Roasted	Boiled	Pudding	Bread
Poshilo Makai-2	71.8 (I)	28.2 (VI)	II	III	I	II
Poshilo Makai-1	69.7 (II)	30.3 (V)	III	I	III	I
Farmers' local	68.2 (III)	31.8 (IV)	IV	V	V	VI
S01SIWQ-3	65.8 (IV)	34.2 III)	I	IV	II	III
S01SIWQ-2	63.2 (V)	36.8 (II)	VI	II	IV	V
Corralejo S99SIWQ	63.0 (VI)	37 (I)	V	V	VI	IV

Note: *I the best.

Source: Koirala et al., 2009

Pro-vitamin A Maize: Poor quality diets, characterized by high intakes of staple foods and low consumption of animal and fish products, fruits, legumes, and vegetables cause micronutrient malnutrition. Scientists have developed new strains of maize (Pro-vitamin A) which provide not only increased levels of pro-vitamin A but also higher yields to farming communities. The vitamin-fortified maize could be introduced instead of maize modified by genetic engineering, a process that continues to face objections. Micronutrient deficiencies can be devastating. Up to half a million vitamin A deficient children go blind every year, half of them dying within a year of losing their sight; and iron deficiency is damaging the mental development of 40-60% children in developing countries. Beta-carotene contained in pro-vitamin A converted into vitamin A when the maize is eaten. Vitamin A deficiency retards growth, increases risk of diseases, can cause reproductive disorders and blindness (Pfeiffer and McClafferty, 2007).

Each year in Nepal, vitamin A deficiency is responsible for the deaths of 9000 children and for 2500 children becoming permanently blind as reported by Fiedler (2000) and was reduced to the deaths of approximately 6,900 children by 2012 (World Bank). In 1993, the government of Nepal initiated the National Vitamin A Programme by distributing high-dose vitamin A capsules to all children 6 to 60 months of age during twice-yearly campaigns (Fiedler, 2000). This program prevented blindness in approximately 2,000 children each year, and was found to reduce under-five mortality in Nepal by about half between 1995 and 2000 (Gottlieb). Researches are on-going in this regard in Nepal (Koirala et al., 2015c).

Hybrid maize

NMRP developed hybrids: Hybrid maize technology has made significant yield advances and increased profitability, and to

Fig. 12: Rampur Hybrid-6

Fig. 13: Rampur Hybrid-4

Fig. 14: Rampur Hybrid-2

Source and Location: Koirala et al., 2014b; NMRP Rampur some extent provided employment opportunity. Despite the high demands for hybrids, research on hybrid variety development is limited in Nepal due to the lack of trained human resources, infrastructure and investment from both the public and private sectors. There is a Source and Location: Dhami et al., 2013; Khumaltar, Lalitpur limited hybrid varietal selection

Fig. 15: Khumal Hybrid-2

option in Nepal. Five single cross hybrids have been released and two heat stress resilient hybrids namely Rampur Hybrid-8 and Rampur Hybrid-10 have been registered. The first Nepali hybrid "Gaurav" could not reach to farmers’ field due to non- synchronization of parental lines creating problem to commercialized F1 seed production. Farmers have been demanding hybrid seeds and a number of hybrids are being marketed every year across the Terai and Inner Terai regions of Nepal. Farmers are being cheated by local dealers of MNCHs based in India while purchasing hybrid seeds due to open boarder. NMRP has been conducting research activities to develop locally adapted, disease resistant and high-yielding maize hybrids. Area under hybrid maize and quantity of seed required for that area was estimated to be 85000 ha (10%) and 1275 ton in 2010 and is projected to reach about 250000 ha and 3750 ton, respectively in 2025 (SQCC, 2013).

Heat Stress Resilient Hybrid Maize for Nepal: Maize planted in maize–rice system is

Fig. 16: Rampur Hybrid-10

Source and Location: Koirala et al., 2017a; NMRP Rampur

Fig. 17: Rampur Hybrid-8

Source and Location: Koirala et al., 2017a; NMRP Rampur

estimated to be about 15.5% of the total maize area and is under spring maize are mostly affected by heat stress, and yield losses may reach up to 75% (Koirala et al., 2013). A record drop in maize production was reported in many maize-growing areas of the world (Van der Velde *et al.*, 2010). It is predicted that maize yield might be reduced up 70 % due to increasing temperatures (Khodarahmpour *et al.*,2011). Mainly anthesis and silking of spring maize coincide with high temperature which results leaf firing and tassel blast resulting poor pollination. It is well proven fact on maize that when temperature rises above 38^0C, pollen grains burst and silks do not emerge at all resulting very poor pollination, and barren ears. Crafts-Brandner and Salvucci (2002) reported that net photosynthesis was inhibited at leaf temperatures above 38°C, and the inhibition was much more severe when the temperature was increased rapidly rather than gradually. Transpiration rate increased progressively with leaf temperature, indicating that inhibition was not associated with stomata closure. In spite of the existence of this promising source of heat stress tolerance, tropical maize genotypes sometimes show undesirable agronomic traits as tall plants, excessive foliage, very long cycle and poor harvest index (Fischer and Palmer, 1984). Heat stress reduces grain yield due to a decline in harvest index (Ferris et al., 1998 and Craufurd et al., 2002). This response usually takes place when above-optimum temperatures occur around flowering, and is linked to their negative effects on kernel set (Vara Prasad et al., 1999). In maize, these effects were primarily attributed to reduced pollen shed (Schoper et al., 1987) and pollen viability.

With a view to tackle this problem, heat stress resilient maize hybrids received from CIMMYT Hyderabad were experimented at NMRP, Rampur; Regional Agricultural Research Station (RARS), Nepalgunj and Agricultural Research Station (ARS), Surkhet during 2013/014, 2014/015 and 2015/016. Total fifty-seven experiments consisting of 7764 genotypes were conducted. At RARS Nepalgunj and ARS Surkhet planting was managed in such a way that anthesis and silking coincide with temperature around/above 39^0C. The selected 24 hybrids were demonstrated including four NMRP developed hybrids and two multinational company hybrids from Pioneer and Monsanto companies as checks. The two hybrids, CAH 151 and CAH 153 performed better and preferred by stakeholders across the demonstration sites than others and registered as Rampur Hybrid-8 and Rampur Hybrid-10 for general cultivation (Koirala et al., 2017b).

Table 9: Hybrid Maize Varieties Developed and Released/registered by National System

SN	Hybrid Variety	Released/registered Year	Source	Yield, ton/ha	Maturity Days	Recommended Domain
1	Rampur Hybrid-10	2017	CIMMYT, Hyderabad	8.79		Terai and Inner Terai up to 700 Metre during Winter
2	Rampur Hybrid-8	2017		9.18		
3	Rampur Hybrid-6	2016	CIMMYT	6.8	158-165	Terai and Inner Terai up to 700 Meter during Winter
4	Rampur Hybrid-4	2016	CIMMYT	6.95	155-165	Terai and Inner Terai up to 700 Meter during Winter
5	Khumal Hybrid-2	2014	Korea	9.08 8.5	152-Winter 138-Summer	Midhills (Rainy Season) and Terat, Inner Terai (Winter Season
6	Rampur Hybrid-2	2012	CIMMYT/Nepal	7.0 3.55	130-160 Winter 125 Summer	Terai and Inner Terai (East of Narayani River)
7	Gaurav Hybrid	2003	CIMMYT	8.1	110-150	Terai and Inner Terai, Winter Season

Source: Joshi et al., 2017

Multinational Companies' Hybrids (MNCHs): As a short term strategy, to fulfil the immediate demand of hybrid growers, NMRP has been testing MNCHs in Nepal. MNCHs were registered based on the information provided by the respective seed company during 2010 and 2011 but the hybrids registered in 2012 onwards were based on data of the multi-location experiments coordinated by NMRP, Rampur. Fifty-five MNCHs have been registered in Nepal till date. Now onwards, at least two years data, having minimum grain yield of 7 ton/ha, anthesis silking interval (ASI) not more than four days and disease/insect pest's score should be 2.5 or less for registration of MNCHs.

Participatory Variety Selection (PVS) and Community Based Seed Production (CBSP): In Nepal, formal seed system comprises seed production by farms and stations of Nepal Agricultural Research Council (NARC) and Department of Agriculture (DoA), contract seed production by National Seed Company Limited (NSCL), Salt Trading Corporation Limited (STCL), Non Governmental Organizations (NGOs) like CEAPRED, LIBIRD, FORWARD, and other seed companies, Community Based Seed Production (CBSP), District Level Seed Self Sufficiency Program (DISSPRO) and seed imports (Joshi, 2015). Adoption of new crop varieties in Nepal is relatively poor. It might be because many varieties do not meet farmers' consumption and management preferences. A crop variety performing excellent under optimum conditions is recommended to a larger geographical area. These tested varieties upon exposure to the real farmers' field situation not always perform well and farmers have been reluctant to adopt them (Joshi, 2002). There is no guarantee that the released variety will meet farmers' needs. In addition, farmers are rarely involved in the research process at the initial stage. Till date, farmers have to depend on other organizations for choosing the new variety seeds for their use. To overcome these problems, PVS has evolved as one of the innovative approaches to complement the conventional variety development and dissemination process.

PVS is the selection of farmers' preferred varieties of different crops by themselves in their own fields under their own management. The main objective of PVS is to overcome the bottleneck of the diffusion of farmers' preferred varieties and to provide varietal selection options to fit in the niche environment. Once the variety is identified, farmer-to-farmer dissemination of PVS variety is the most common process of varietal diffusion. Participatory research can be used to empower farmers and promote development in farmers' communities. It can also be used to increase the efficiency of formal breeding programs in developing and popularizing varieties suitable for resource-poor farmers. The rejection of released varieties by farmers, who do not adopt them, and the rapid and high adoption by farmers of non-released varieties are the successful examples of PVS. The PVS approach helps to identify farmers' preferred varieties in their own field under their own management within a possible shortest period of time and provides varietal selection options (Witcombe et al., 1998; Joshi and Witcombe, 2001; Weltzien Eva et al., 2002; Koirala et al., 2005) using mother-baby trials (Koirala, 2012). Collaborative participation allows farmers to decide overall which variety/varieties they prefer as a simpler and more effective solution.

Among various inputs required in agricultural farming, seed is the cheapest and basic input. Seed is the ultimate technology which encapsulates a package of disease resistance, quality and yield potential. Use of quality seeds alone could increase productivity by 15-20% indicate the critical role of seed in agriculture. Unavailability of farmers' preferred varieties at right time, with desired quantities and reasonable price is another major constraint in inaccessible areas of remote hills and areas where formal sector cannot reach resulting in low adoption of improved varieties and low productivity (Koirala et al., 2011 and 2015b). CBSP of OPVs in public private partnership (P3) is found very promising in helping resource poor farmers to improve their income and food security.

Crop Management

Resource Conserving Technologies (RCTs): Labour scarcity, increasing production costs and sluggish or static productivity are the major challenges of maize based production systems in Nepal. Conservation agriculture (CA) promotes reverse degradation processes, improves resource quality, reduces production costs and helps achieve sustained high productivity. Yield and its components of spring maize did not vary due to tillage practices, however the cost of cultivation was reduced significantly (35%) due to no tillage with residue over conventional tillage in the first season. Weed density also reduced by 69% in no till with residue kept field as against the conventional tillage. Irrespective of tillage practices, field with weed free had the highest grain yield of 5.6 ton/ha followed by the field treated with Atrazine @ 0.75 kg a.i./ha + one hand weeding (4.7 ton/ha) and Atrazine @ 0.75 kg a.i./ha + Pendimethalin @ 2.0 ml/litre of water (PE with tank mixture) produced the grain yield of 4.4 ton/ha. Similarly, weed biomass was also found negatively correlated with the grain yields of maize (Koirala, 2014).

Table 10: Effect of Tillage, Genotypes and Planting Geometry on Maize

Treatment	No. of Ears/ha	Grain Yield, ton/ha	Maturity Days
Tillage			
Conventional tillage	62120	8.35	133.83
No tillage	64962	8.36	130.72
F-test	*	ns	**
LSD (0.05)	1831.1	-	0.48
Genotype			
Rampur Hybrid-2	64205	8.32	131.78

Treatment	No. of Ears/ha	Grain Yield, ton/ha	Maturity Days
Rampur Hybrid-4	62876	8.39	132.78
F-test	ns	ns	**
LSD (0.05)	-	-	0.48
Planting geometry			
60 x 25 cm^2	64942	9.24	133.58
70 x 25 cm^2	63603	7.95	132.42
75 x 25 cm^2	62077	7.88	130.83
F-test	*	**	**
LSD (0.05)	2242.7	0.72	0.59
CV, %	4.2	8.3	2.5
Grand mean	63541	10.36	132.28

Source: Koirala, 2014

Table 11: Effects of CA based Practices on Yield Parameters and Yield of Maize in the Hills of Nepal

Treatment	Ear Diameter, cm	Ear Length, cm	Grain Yield, ton/ha	Test Weight, g
Conventional tillage	4.932	14.6	4.752	262.5
No tillage	5.197	15.8	5.212	263.9
LSD (T)	0.21	0.38	0.795	0.79
Residue removed	4.675	14.4	3.887	261.4
Residue kept	5.454	16.1	6.076	265.1
LSD (R)	0.19	0.38	3.275	3.28
LSD (T x R)	0.18	0.54	0.432	0.43
Manual weed control	5.031	14.8	4.908	262.6
Herbicide	5.098	15.6	5.056	263.8
LSD (W)	0.05	0.38	3.05	3.05

Source: Koiala, 2014

Similar grain yield of maize was found in no tillage (NT) and conventional tillage (CT), with and without residue, manual and herbicidal weed control but higher yield recorded in recommended doses of fertilizers (RDF) than farmers' doses. Planting geometry of 60 x 25 cm^2 produced the highest grain yield of maize (Table 10). Table 11 reveals that higher grain yield of maize was found in no till, residue kept and herbicidal weed control in the hills of Nepal.

Weekly Maize Planting to Address Climate Change Issue: To tackle the problem of climate change, four varieties of maize are planted each week on Wednesday at NMRP Rampur. The findings of experiments showed that early maturing maize variety Arun-2 produced the highest grain yield in Aug./Sep. Based on two years planting results the lowest yield was in April/May (1.923 ton/ha) and in May/June (1.063 ton/ha). The full season variety Rampur Composite produced the highest yield in Feb./March and in Aug./Sept. but the lowest yield was in Nov./Dec. and in May/June. Gaurav hybrid produced the highest yield in July/Aug. but the lowest yield in Nov./Dec. and in May/June.

Table 12: Interaction Effects of Variety and Date of Seeding on Maize Grain Yield (ton/ha)

Sowing Month	Poshilo Makai-2	Rampur Hybrid-6	Rampur Hybrid-4	Manakamana-7
Apr./May	2.958	5.225	4.843	2.624
May/June	3.436	4.160	4.619	2.298
June/July	2.940	4.357	5.158	4.819
July/Aug.	4.141	7.191	7.247	4.252
Aug./Sep.	3.744	7.393	6.877	4.161
Sep./Oct.	5.042	7.479	6.589	5.836
Oct./Nov.	4.835	5.798	6.060	5.494
Nov./Dec.	3.556	5.508	5.438	4.355
Dec./Jan.	3.110	4.400	4.712	4.088
Jan./Feb.	3.580	7.017	7.686	5.454
Feb./Mar.	4.403	7.297	6.850	4.276
Mar./Apr.	3.595	6.155	6.283	3.953

Source: Koirala, 2014

Rampur Hybrid-4 produced the highest grain yield of 9881.4 ton/ha planted in 3rd of Jan. followed by 9364.8 ton/ha in 21st March and 8497.9 ton/ha in 29th Aug. at Rampur. Likewise, genotype Poshilo Makai-2 produced the highest grain yield of 5246 ton/ha in 31st Jan. followed by 5241 ton/ha in 21st March planting. The interaction effects of variety and date of seeding on grain yield of maize at NMRP from 14^{th} April 2013 - 13^{th} April 2014 have been summarized in Table 12. This type of research is needed for each new variety that is going to be released at particular location.

Improved Crop Management Practices:

- Land preparation: As per recommendation
- Sowing season: Spring, summer and winter
- Seed rate: 20 kg/ha
- Spacing: 75 x 25 cm^2 (for OPVs) and 60 x 25 cm^2 (for hybrids)
- Fertilizer: 120:60:40 NPK kg/ha (for OPVs) and 180:60:40 NPK kg/ha (for hybrids) along with 10-15 ton/ha FYM
- Intercultural operations: As per recommendation
- Harvesting: After physiological maturity

Pathological Research: Maize genotypes are screened against major diseases in the hot spot and under artificial inoculated conditions in different agro-ecozones of Nepal. High yielding and resistant genotypes against major diseases such as Grey Leaf Spot (GLS), Banded Leaf and Sheath Blight (BLSB), Ear Rot, Northern Leaf Blight (NLB) and Southern Leaf Blight (SLB) are being screened.

Entomological Research: Genotypes tolerant against maize stem borer (*Chilo partellus* Swinhoe) infestation in field condition identified are Manakamana-7, BGBYPOP, Rampur-4, Arun-3, Arun-4, Poshilo Makai-2, Rampur Hybrid-4, Rampur Hybrid-6, RML-95/RML-96, RML-87/RL-105 and RML-86/RML-96.

Soil Fertility Management: Response of NPK levels on growth, grain yield and yield attributes are on-going activities. The recommended dose of fertilizer for full season and early maturing as well as for summer, spring and winter maize is the same (120:60:40 N:P:K kg/ha) till date in Nepal. Based on a two-year experimental data the recommendation will be revised.

Other Management Practices to Increase Production and Productivity of Maize

- **Seed Priming:** Maize seed priming is a technology where seed is soaked in water for a period that is less than "safe limit", that is 16-18 hours. Then are simply surface dried by spreading the seed in the shade for 15-30 minutes, and sown the same day. A two-day workshop on seed priming held in Nepal on May 16-17, 2001 also highlighted the importance of seed priming and yield advantage of this technology on different crops up to 200% (Krishi. 2058 BS). Seed priming as a low cost, low risk intervention that increases and stabilizes yield has a large impact on livelihoods of small scale, marginal and resource-poor farmers and families.

Yield and other advantages of primed seeds over non-primed are recorded in different crops in different countries. There has been much research to test, develop and promote on-farm seed priming in a range of crops, countries and agro-environments. The beneficial effects of priming on crop establishment, development and yield have been well documented (Parera and Cantliffe, 1994; Chivas et al., 1998; Kulkarni and Eshanna, 1998; Harris et al., 1999, 2001, 2002; Anonymous, 2002; Jasi et al., 2000; Krishi, 2058 and Koirala, 2017).

Seed priming experiments conducted in western hills of Nepal in farmers' field using mother-baby scheme when combined over locations revealed that primed treatments in maize silked three days earlier and matured six days earlier compared to non-primed counterparts. Likewise, increased number of plants and ears per plot in the primed treatment was observed. Significant increase in grain yield (average of 11.6% and maximum of 27.8% in Manakamana-1) was recorded. Priming effect for grain yield was found not only variety specific but also location specific. Highest grain yield was obtained from the variety Manakamana-3 both in primed (6028 kg/ha) and non-primed (5344 kg/ha) condition. Farmers' response in baby trials combined over locations showed that plant stand after germination in primed treatment was found better as reported by 80% of the respondents. A total of 78% respondents claimed earlier maturity in Manakamana-5, whereas more than 60% respondents claimed the same for rest of the varieties. Among the respondents, 75.1 to 88.9 % express their desire to use maize seed priming technology in the coming years (Koirala, 2017).

Variety and location specific results on maize seed priming were recorded in Nepal. Therefore, this technology should be promoted and disseminated widely using different varieties at various locations.

- **Detasseling:** It is the removal of tassel prior to pollen shed or before silk emergence for various purposes. Generally, detasseling plays an important role in hybrid seed production, and breeder and foundation seed production of open-pollinated varieties. Maize is protandrous in which pollen shedding normally begins 1-3 days before the emergence of silk and continues 3-4 days after the silks are ready to be pollinated. It is estimated that a single tassel may produce as many as 25,000,000 pollen grains or an average over 25,000 pollen grains for each kernel on an ear with 800-1000 kernels. Pollen grains remain viable for 12-18 hours if weather condition is normal. The anthesis (dehiscence of anthers) starts from the central shoot of the tassel from top and proceeds downwards. The detasseling period usually lasts about 2 weeks but may range from 1 to 5 or more weeks. This period may be prolonged in fields which have delayed and non-uniform germination, variation in soil fertility, water logging in early stages, significant pre-flowering water stress, heavy insect infestation resulting in plant stunting, and high incidence of foliar diseases. Tassels are removed to achieve necessary genetic purity and to increase seed/grain production of maize crop.

- **Achieve Necessary Genetic Purity:** Detasseling of all female plants is practiced in hybrid seed production before pollen shedding and silk emergence. At the onset of flowering, workers must begin a thorough and consistent inspection of the maize seed fields to remove tassels from the female rows. Likewise, in breeders and foundation seed production plots of open-pollinated varieties, female rows should be detasseled daily. Tassels from off-type and diseased plants from male rows also should be removed to prevent pollination from these undesirable plants. We could not see uniformity in different quantitative traits of OPVs as in hybrids. Therefore, to control maturity period of that particular variety, tassels emerged in the beginning (1-2 days) and tassels emerged after when 90% of the plants are pollinated should be detasseled.

Increase Production of Maize Crop: Tassels should be pulled when they are well out of the "boot". This often occurs 1 or 2 days after the tassels are first visible. If the pulling is done prematurely, 1 or 2 leaves may be removed with the tassel, or the tassel may break off and not be completely removed. This is undesirable because loss of leaves will reduce seed yields. Detasseling also minimizes shading effect promoting photosynthesis. After detasseling, energy required for growth and development of pollen grains diverts to kernel resulting bold grain size compared to grains of non-detasseled plants (Table 13). Removed tassels are nutritious fodder for livestock.

Table 13: Mean Yield Changes of 10 Inbreds Following Tassel and Leaf Removal

Treatment	Yield Change (vs. tassel), %	Yield Change (vs. control), %
Tassel only	------	+6.9
Tassel + 1 leaf	-1.5	+5.8
Tassel + 2 leaves	-4.9	+2.1
Tassel + 3 leaves	-13.5	-6.8

Source: Hunter et al., 1973

Potential Scaling-up of Proven Technologies for SAARC Countries

- **Potential up-scaling Techniques adopted in Nepal**

In Nepal, different up-scaling techniques/methodologies are being adopted for promotion and wider dissemination of promising maize technologies by NMRP. Some of them are as follows:

- Involvement of public and private sectors in the research/demonstration blocks while selecting promising technologies/varieties
- Farmers' mobilization training
- Training to farmers, researchers, extension and development workers
- Large plot demonstration of promising/pipeline technologies for promotion and wider dissemination in the targeted environments
- Participatory evaluation of experimental and demonstration plots by farmers, researchers, extension workers and media representatives
- Farmers' day celebration at experimental and seed production sites
- Inter-district/inter-site observation tour of stakeholders including media representatives to share knowledge and experiences at other sites/districts
- Travelling seminar
- Talk program
- Implement farmers' field school program
- Mother-baby scheme of participatory variety/technology selection
- Preparation and distribution of extension materials in English/ Native language

- Publication through press and electronic media
- Stakeholders' workshop

Post-harvest Handling

- Not sufficient research carried out
- **Seeds**

- Seed certification according to category of seeds
- Harvested after physiological maturity
- Sun drying up to kernel moisture 12%
- Seed treatment with Malathion and Bavistin @2-3 g/kg seed
- Bagging (10-30 kg in cotton or jute bags) and tagging
- Storage in well ventilated room
- Super grain bags are also used
- Seed bins are used to store the seeds after sun drying

- **Grain**

- Winter maize sold immediately after harvest mainly for poultry feed
- Attention not paid on physiological maturity for summer and spring maize
- Store long period in heap
- Huge loss due to high moisture
- Dehusked ears or ears with husk are stored in local structures
- Huge loss due to storage grain pests and diseases

Value Addition

- Promotion of OPVs and hybrids of normal, QPM and pro-vitamin A maize aggressively

Seeds

Assurance of quality as per standards of seed category and requirements as per recommendation are maintained. Grading, seed treatment, tagging and bagging are strictly followed.

For consumption

- Green roasted ears
- Baby corn
- Pop corn
- Industrial usages: Grits, flour, corn flakes, glucose
- Stay green character to use as fodder for livestock

- QPM and Provitamin A maize for food, feed and nutritional security

Potential Scaling Up of Proven Technologies for SAARC Countries

- Mapping maize mega-environment in SAARC countries and promotion of identified technologies (varieties and others) at similar environments (HTMA already initiated)
- Promote public-private partnership (PPP) for identifying farmers' preferred technologies (eg. variety, date of sowing etc.)
- Promote CBSP program where formal sector is not strong enough to fulfil the location specific demand
- Sub-licensing of hybrids to private partners for hybrid seed production and dissemination

Key Policy Inputs for Improvement of Proven Technology of Maize Crop in South Asia

Key Policy Issues for Nepal: Productivity and competitiveness of the agriculture sector are low; adoption of improved technology is limited and there is a growing food trade deficit and malnutrition is high. In Nepal, about 13% of the population is considered to be moderately to severely food insecure, and 35 out of 75 districts are classified as food insecure with respect to food grains (MoAD, 2017). Poverty is still widespread (25% of the population) and most of the poor are in rural areas. ADS (2014) aims at increasing self-sufficiency in food grains and thereby reducing poverty in rural areas, respectively from 5% trade deficit to 0-5% trade surplus, and 27 to 10% from base year 2010 to its completion. ADS targets to reducing food poverty from 24 to 5% by the end of the strategy as compared to base year 2010. Likewise, ADS has put target of annual agricultural growth from 3 to 5% after 20 years. Among the development regions, stunting is highest among children in the mid-western region (50%) (MoHP, 2012). ADS (2014) has planned to reduce stunting, under-weight, wasting and women with low body mass index (BMI), respectively from 41.5, 31.1, 13.7 and 18% (base year 2010) to 8, 5, 1 and 5%, by its completion. The lysine and tryptophan-fortified maize could be introduced instead of normal and maize modified by genetic engineering. To allow children between one and two years old to grow at twice the normal growth rate, the energy requirement must be raised 4%, but the protein requirement must be increased about 30% (FAO/WHO/UNU, 1985).

Increasing crop productivity, raising income and generating employment through self sufficiency, import substitution and export promotion of quality seeds are the aims of Seed Sector Development Strategy (Seed Vision 2013 - 2025). The conceptional framework of seed vision is based on seed value chain including inputs and outputs of the seed chain components: variety development and maintenance, seed multiplication, processing and conditioning, seed marketing and seed use.

Seed vision envies doubling the number of location specific high yielding competitive varieties and increase improved seed production threefold through formal system by 2025. As envisioned in National Seed Vision 2013-2025 (SQCC, 2013) by 2025, projected SRR is about 25% for cereals and 31.57% for maize with average maize yield of 3.33 ton/ha. Total 40 maize varieties need to be released, and among them, 12 and 5 maize hybrids will be developed and promoted to meet the growing domestic demand by public and private sectors, respectively. It highlights the importance of hybrid maize technology not only for increasing production and productivity, but also for increasing employment opportunities in rural areas and as an import substitution measure.

Key Policy Issues for South Asia

- Free exchange of germplasm within SAARC countries
- Formation of SAARC maize working group (SMWG)
- Formation of SAARC trials
- SAARC maize workshop
- Crop insurance at SAARC level
- Experience sharing and scientific visit program
- Similarity in subsidy

Challenges and Way Forward for Maize Research and Development in South Asia

Constraints

- Low productivity of major cereals
- Limited varietal selection options
- Low seed replacement rate
- Costlier quality seed
- Unavailability of required inputs as and when needed
- Increasing cost of inputs (fertilizers, seed, irrigation water etc.)
- Unavailability of labour and less mechanization
- Inadequate crop management technologies (e.g. plant population)
- Outbreak of new maize diseases (GLS) and insects (Pollen beetle)

Challenges

- Big yield gap (3.5 ton in Nepal)
- Hybrids - limited resources
- Seed demand - increasing but supply limited
- Poor human and physical resources
- Climate change (increased incidence of drought, heat, cold stress and flood)

Opportunities

- Diverse climate and production environments
- Diverse cropping patterns
- Scope of bridging the maize yield gap in Nepal
- Ultimate food for mid hill people and raw materials for industries
- Diversity in uses (food, feed, fodder, fuel and other industrial uses)

Way Forward

- Cooperation and collaboration among SAARC countries for maize research and development
- Promotion of hybrid maize technology in potential pockets
- Develop stress resilient technologies to tackle climate change issues (heat, drought, cold, diseases, insects etc.)
- Sharing of promising technologies among SAARC countries

Conclusion

Maize is an important crop with high yield potential and broad genetic base. It is grown from Terai to mountain regions of Nepal. It is pivotal in food and nutritional security in mid and high hills; and feed and fodder security in Terai region of Nepal. New maize technologies are being developed across the globe and achievements are being shared through CIMMYT and other CGIAR partner organizations. New technologies identified, developed and verified by researches have been promoted by educational and extension systems. Because of similarities in agro-climatic conditions among SAARC countries, the technologies identified as promising in one coutry should be shared among each other for the benefit of the region. New technologies viz. hybrids, QPM, pro-vitamin A, resource conservation technologies; rational and scientific uses of inputs should be promoted aggressively. Thus, amidst all the challenges and difficulties, cooperation and exchange of ideas, technology and vision among SAARC countries can bring food, feed and nutritional security ultimately reducing poverty.

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Proven Technology for Maize Improvement through Participatory Approach in Pakistan

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Introduction

Maize (*Zea mays* L.) is a short duration seasonal crop with comparatively higher yield potential among the cereals. It is of huge importance in countries like Pakistan where the population has disproportionately increased and is facing with shortages in food supplies. In hilly areas, it is the staple food but the earlier start of snow fall and chilling period are the limiting factors for maize successful cultivation. Maize has the genetic potential to grow in a wider range of climatic conditions (Ferdu *et al.*, 2002).

In mountainous areas, it is used as food where it is cultivated approximately on 25% of the total area. In Pakistan, maize is used as food, poultry and animal feed and fodder (Araus *et al*., 2002). Starch production from maize is the major objective for the farmers supplying their produce to wet-milling industry. Direct maize consumption in Pakistan is declining but its use as major ingredient in the animal and poultry feed is growing at a higher speed than anticipated. Currently, around 40% of the production is utilized in animal feed where it is used in the preparation of starch, glucose, corn feed, and corn gluten (Hussain *et al*., 2006). In addition to feed, it is used as raw material specifically in paper, textile, laundry, refining and food industries (sweetening of candies, ice-creams or bakery products) and chemical industries as well (Chaudhry, 1983).

Maize yield in Pakistan can be uplifted three times to convene the increasing food and feed requirements of the country by employing better management practices, while excessive and limited water supply affects the growth of maize (Zaidi *et al*., 2007). In Pakistan, the total area under maize production is around 1144 thousand hectares with the annual production and mean yield of 4.920 million tonnes and 4301 kg/ha, respectively (GOP, 2015-16). Major part of land under maize (0.32 million hectare) is rainfed which is mostly in the northern areas of Pakistan and Kashmir where the average production per unit area is very low as compared to the irrigated areas (GOP, 2007). In Pothwar region, rainfed maize is grown in autumn season with the start of monsoon season, which lasts enough to supply water for 75-80 days to support the crop and fulfill the requirement of milky stage.

Proper agronomic practices are essential for the efficient utilization of rain water which should be aimed to reduce surface run-off and accumulate it in the crop root zone for its use during moisture stress (Belachew & Abera, 2010). Planting technique is one of essential factors for improving crop yield. According to Abdullah *et al*. (2008), ridge planting significantly increased maize yield as compared with other sowing techniques. Traditional planting of maize on flat has some disadvantages. Flood irrigation in that case causes reduction in water use efficiency and accumulation of nitrogen fertilizer in areas of the field with depressions. Flood irrigation also causes hard crust formation which badly affects the germination and later on, it can lead to higher chances of lodging. A raised bed planting technique with furrow irrigation can overcome these disadvantages associated with flat planting (Nasir & Akbar, 2000; Govaerts *et al*., 2005; Wang *et al*., 2004). The use of hybrid seed and better agronomic practices tremendously contribute to yield (Dong *et al.*, 1993; Dwyer *et al*., 1991).

Pakistan is a country with around 170 million populations with 2% per year increase (Kazi, 2010) and falls in the subtropical region (24-37^{o} N and 60-75^{o} E) with monsoon precipitation mostly occurring from June to August. The economy of Pakistan is based on agriculture which has an important influence on our socio-economic set up because it employs around 66 % of the country’s available labor force (GOP, 2009) The productivity can be augmented in rainfed areas by employing appropriate agronomic practices with better resource management.. Water saving techniques and irrigation scheduling may be adopted for more efficient utilization of water which is becoming limiting factor in agricultural production. Deficit irrigation is the one way of maximizing water use efficiency for higher yields per unit of irrigation water applied to the crops. The water stress, given before anthesis affects the yield (Taylor and Prusinski, 1990).

Different water conservation techniques i.e. bed, furrow, broadcast and flat planting affect soil water potential and leaf water potential (Quanqi *et al*., 2008) as well as competition among the individual plants and air circulation (Ayub and Shoaib, 2009). Traditionally maize has been a popular option in certain geographic areas but with advances in hybrid performance and agronomic techniques, the success of the crop has increased (Orosz *et al.*, 2009).

Sandhu and Hundal (1991) reported that ridge sowing decreased the period from sowing to tasseling and silking and so to the maturity. Bakht (2006) concluded that days to 50% tasseling and silking were significantly affected by planting methods in addition to the nitrogen levels. Maximum number of leaves plant^{-1}, number of cobs plant^{-1}, number of grains cobs^{-1}, taller plants, grain and biological yield was recorded when planting was done one ridge planting with 200 kg N ha^{-1} as compared with other treatments. Findings of Abdullah *et al*. (2008) and Sandhu and Hundal (1991) showed that ridge planting significantly enhanced maize yield when compared with other planting techniques. While Nasir and Akbar (2000), Govaerts *et al*. (2005), Wang *et al*. (2004) and Ortega *et al*. (2008) reported that raised bed planting was the most successful method of maize planting. Ahmad *et al*. (2008) reported that flat planting with earthing up and ridge sowing with one rows proved equally good in terms of yield performance but the lodging was comparatively lesser in the flat planting. The findings of Sharma and Saxena (2002) proved the superiority of trench planting due to lesser water requirements, lesser level of lodging and more yield as compared to the ridge and flat planting methods. Khan *et al*. (2012) reported that ridge sowing enhanced the root elongation and development and so it proved better in terms of yield output as compared to other methods. Planting methods are very important because they affect photosynthesis, water use efficiency, radiation use efficiency and so ultimately the economical yield of maize (Dwyer, *et al*., 1991; Tollenaar and Aguilera, 1992).

Yousef and his colleagues (2001) investigated the effect of planting pattern and plant density on the yield and yield components of two maize hybrids and two cultivars. Increased grain and biological yield was recorded with the increase in the plant density, whereas the level of the yield components decreased with increase plant density. The single cross hybrid performed better in terms of grain and biological yield as compared to the three-way cross hybrids. While the two cultivars showed non-significant differences in the values of components contributing to the yield except for 1000-grain weight. Alias *et al.* (2010) reported that grain and biological yield can be increased by in increasing the plant density up to certain level after which they tend to decline because crop bareness gets enhanced due to higher plant density due to greater gap between tasseling and silking. The hybrids differ in their response to plant density and the amount of K application due to their different genetic constitutions (Sener *et al*., 2004; Alias *et al*., 2010). The plant bareness due to higher plant density, which causes widening gap between tasseling and silking, lead to lower yield because of lesser number of grains per cob (Khan *et al*., 1999) and lesser number of grain rows per cob (Esechie, 1992) which ultimately results into lower grain yield. Similar findings were reported by Singh and Srivastava (1991).

Ayoola and Agboola (2002) studied the effect of two planting patterns and the level of organic/inorganic fertilizers on the growth and yield of maize in cassava/maize/melon inter-cropping system. The results, Ayoola and Agboola reported that planting pattern had no significant effect on the growth of maize at the early stage, but at the later stages, the growth and yield were significantly affected. The grain yield was significantly higher under triangular planting pattern than rectangular planting pattern. The results also indicated that maize crop performed best when a combination of inorganic and organic fertilizer was applied as compared to the crop when only one of two fertilizers sources was applied.

Saif et al. (2003) studied the effect of different planting patterns and irrigation levels on the growth and yield of maize. Planting patterns did not influence growth and yield significantly which is not consistent with the results reported by Ayoola and Agboola (2002) mentioned earlier. But the irrigation level significantly affected the number of plants/plot at harvest, number of grains/ cob, 1000-grain weight, biological yield, grain yield, and harvest index. Maximum grain yield (7.49 t/ ha) was obtained under 30/90 cm spacing, double row strips (30 cm from row to row and 90 cm from strip to strip), and six irrigations. Nissen *et al*. (1988) also reported reduction in yield and yield contributing factors by the moisture stress. Similar results regarding decrease in yield and yield associated traits as a result of water stress were also reported by Khan *et al*. (2001), Dhillon *et al*. (1996) and Jun-Chen and Dai-Junying (1996). Saeed *et al.* (1997) reported that water stress during vegetative stage delayed tasseling and silking. While generally, the crop matured earlier under drought stress which affected all the yield and yield contributing factors negatively.

Shah *et al*. (2003) studied six planting patterns. The results suggested that water use efficiency was the maximum (14.58 kg/ha mm) when the crop was sown using 60 cm and 90cm planting pattern. The water use efficiency was the lowest (8.01 kg/ha mm) when the crop was planted on the ridges and the irrigation was given to the alternate furrows. The grain yield due to larger leaf area per plant and 1000-grain weight was also the highest (4.47 t/ha) in 60cm and 90cm planting pattern. It is evident from the above account that the planting pattern affects the water use efficiency and water use efficiency can be enhanced by employing a better planting method (Mohsan *et al*., 1989). Jan *et al*. (2009) reported that under similar conditions, flat sowing and ridge planting proved superior compared to other planting methods due to higher yield performance. They also reported that these two planting methods proved more rain water use efficient due to minimum runoff loss. It becomes very important in the areas where the water availability is the limiting factor. Mild water stress also improves water use efficiency as an adaptation measure under moisture stress until the stress not severe/prolonged (Saxena, 1985) while higher number of irrigation lowers the water use efficiency. The amount of moisture used by the crop is usually less than 20% of the applied water so the efficient use of water would save a lot of money on the water cost (Balasubramaniyan and Palaniappan, 2001). Choudhary and Qureshi (1991) reported that furrow ridge planting method ensures higher water use efficiency as compared to other planting methods but the results reported by Shah *et al*., (2003) were in conflict with those reported by Choudhary and Qureshi (1991). For having higher water use efficiency, an integrated approach should be adopted including better planting method, drought resistant genotype, wise irrigation schedule minimizing the water losses and of course use of some hormones which might improve the response of the crop under the water stress by protecting it from the damage.

Gozubenli *et al*. (2004) studied two planting patterns to find out the optimum plant population for maize hybrid. Four plant densities were used. The effects of plant number and planting technique on grain yield and some of the yield components (such as stem diameter and grain weight/ ear) were statistically significant. Grain yield gradually increased with increasing plant population up to 90,000 plants/ha followed by decrease at higher plant densities as mentioned earlier and reported by Alias *et al*. (2003). There were no significant differences between 90,000 and 105 000 plants/ha populations. Twin row planting pattern out-yielded single row planting (10398 and 9986 kg/ha, respectively) which showed the twin row planting resulted in 4% higher grain yield than the single row planting without any additional input. It shows that planting pattern ensuring better utilization of the resources can be very useful in getting higher yield at no extra cost.

Agricultural Land Use

The total geographical area of Pakistan is 79.6 million hectares. About 27% of the area is currently under cultivation. Of this area, 80% is irrigated and the country has the world's largest contiguous irrigation system. The rest of the territory is rangeland; where, cropped area constitutes 23.8 million hectares, forests 4.21 million hectares. Agriculture accounts for 21% of the GDP and together with agro-based products fetches 80% of the country's total export earnings. More than 48% of the labor force is engaged in this sector.

Area and Production Status of Maize Crop

In Pakistan, maize is third important cereal after wheat and rice. Maize contributes 2.2% to the value added in agriculture and 0.4% to GDP.

During 2015-16, cultivated area under maize crop has increased to 1144 thousand hectares, showing an increase of 0.2% over last year's area of 1142 thousand hectares. Maize crop production stood at 4.920 million tons during 2015-16, showing a decrease of 0.3% over the last year's production of 4.937 million tons. Currently, except potato maize is the most profitable, stable and dependable crop in the agriculture system of Pakistan. The area, production and yield of maize are given in Table 1.

Table 1: Percent Change in Area, Production and Yield of Maize in Pakistan

Year	Area (000 ha)	% Change in area over last year	Production (000 tons)	% Change in production over last year	Yield (kg/ha)	% change in yield over last year
2015-16	1,144	0.2	4,920	-0.3	4,301	-0.5
2014-15	1,142	-2.2	4,937	-0.1	4,323	0.2
2013-14	1,168	10.2	4,944	17.2	4,233	6.3
2012-13	1,060	-2.5	4,220	-2.7	3,981	-0.3
2011-12	1,087	-	4,338	-	3,991	-

Source: Pakistan Economic Survey, 2015-16.

Table 2: Province wise Area, Production and Yield of Maize

Province	Area (000 ha)		Production (000 tons)		Yield (kg/ha)	
	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14
Punjab	672.8	689.3	4019.9	4020.8	5975	5978
Sindh	3.2	3.5	3.4	3.5	1063	1000
KPK	463	470.9	909.7	914.8	1965	1943
Baluchistan	3.5	4.8	3.8	5.1	1086	1063
Pakistan	1142.5	1168.5	4936.8	4944.5	4321	4317

Source: Pakistan Economic Survey, 2015-16.

Genesis of Maize Improvement in Pakistan

The history of introduction of maize (*Zea mays* L.) into Pakistan is still not clear. It is generally said that the Portuguese introduced maize in the beginning of 16th century through the western coast of India. The use of Muslim terminology (Makki) in its local name seems to suggest that maize has come through Arab African sources.

Research work on maize was initiated in 1953-54 at Faisalabad, which was transferred to Agricultural Research Wing in 1958 and Hybrid

Maize Seed Farm was established. The status of the Farm was raised to Maize & Millets Research Institute in 1968-69. In Pakistan, maize is third important cereal after wheat and rice. Being a C4 plant, having high genetic potential and photosynthesis explorative crop, its average productivity is higher than wheat and rice (Table 1).

Maize Production Zones

- High-wet Mountains
- High Moderate Rainfall Mountains
- High Dry Mountains
- Dry Western Plateau
- Foot-hill Plateau
- Northern Irrigated Plains
- Central Irrigated Plains
- Coastal Irrigated Plains

Crop Rotation

- Maize – Wheat in KPK and AJK
- Maize – Tobacco in Mardan, KPK
- Maize kharif – Maize spring, Punjab
- Rice – Potato – Maize spring in Sutlej valley of Punjab
- Mize kharif – Potato - Maize spring, Punjab
- Maize kharif – cotton in cotton belt, Punjab
- Maize – wheat in rainfed areas

Currently, maize grown in Pakistan is enough for domestic needs and Pakistan is neither surplus nor deficient in maize grain supplies.

Maize Production Technology, Post-Harvest Handling, Value Addition and other Improved Technologies for Research and Development

Sowing Method and Seed Rate

Ridge planting is considered to be the best method of sowing*:* *Dibbling* is a good method of sowing maintaining 6"distance between the plants at depth of 1 ½ -2" on the side of the ridge not at the top to decrease the water needs. Sowing ***by tractor drill/planter/cotton drill*** may be performed by taking a precaution of pre-calibration of the planter for the above mentioned planting geometry. In this way, 25-30 kg seed will be needed for planting one hectare of land with a crop stand ranging between 75-80 thousands plants per hectare.

Fertilizer Application: Hybrids exhibit a stronger/vigorous vegetative phase and a longer reproductive phage for converting inorganic material into organic assimilates thus requiring relatively higher dose of fertilizers. Following schedule of fertilizer doses by multinational, public sector of maize hybrids and OPVs is recommended.

Table 3: Fertilizer Recommendation for Maize (kg/ha)

Crop type	Nitrogen		Phosphorus	Potash
	Basal	Post planting		
Multinational - Hybrid	45	230	115	125
Public sector -Hybrid	45	205	115-170	63-125
OPV - Irrigated	45	155	115	92
OPV - Rain fed	120	0	85	30

Weed Control: The economical method of weed control is herbicide application. Spray of herbicide (Primextra Gold) @ 2.5 liter per hectare within 24 hours after planting under moist conditions is recommended to control the weeds, which otherwise can effect the crop significantly. Afternoon/evening is the proper time for spray. If due to one reason or other field could not be sprayed, the weeds can be successfully control by operating lister cultivator to up-root the weeds between the rows. Traditional practice of hoeing also helps to control the weeds.

Irrigation: Depending on the temperature and relative humidity, crop should be irrigated. However, first watering may be delayed up to 25-30 days after sowing. After that, irrigation is continued with 10-15 days interval. During reproductive period, frequent irrigation is needed, may be twice to once a week according to situation to avoid tassel blasting and good grain filling. Spring crop needs more irrigation water, especially during the latter stages of crop when the temperature is high and crop is grown up.

Insect Control: Maize stem borer and shoot fly are the major pests of maize in Pkistan. Shoot fly's infestation generally occurs at early stages of the crop resulting dead hearts. If seeds are treated with Confidor and Deltanet, this problem can be reduced. Maize stem borer is the most destructive pest and can reduce the yield by 10-30% under normal conditions and sometimes may reach up to 80%. The initial research effort concentrated on the chemical control measure to control the insect. The most effective and economical chemicals, and their time and method of application have been identified. Chemicals (insecticides) are more efficient and quick method of insect control but they are very hazardous directly or indirectly to humen being and animals. Among insecticides, bio-pesticides and granules are safer to some extent. If necessary, spray method can be used. Among granules, Furadan @ 20 kg/ha can be applied in whorls of the plants or can be broadcast when soil is moist. Among spraying insecticides, Karate, Fenvelirate, or any available systemic insecticide @ 500-700 ml per hectare can be applied. The most safe and environmental friendly method of insect control is biological method or growing resistant variety. Biological method is very difficult to establish for every pest.

Because of environmental pollution, hazards to human being and animals, and costlier imported chemical insecticides, the research on host-plant-resistance was initiated at NARC. The main objective of such research activity is to develop germplasm with high level of tolerance for maize stem borer and to make it available to maize breeders to incorporate the desired characteristics in to existing improved maize varieties. A considerable success has been achieved and germplasm BR-1, BR-2 and BR-3 have been identified by Entomologist of NARC through series of observation under natural and artificial conditions. The new material has shown a considerable tolerance for the maize stem borer. The identified donors will be incorporated while developing new OPVs and hybrids.

Diseases Control: Stalk rot and Leaf Blight Diseases are important in maize. Maize stalk rot is a serious problem causing economic losses to maize crop. The continuous selection & introgression of tropical brood in the improved varieties have proved extremely helpful. With these research efforts the recent improved varieties can be grown without confronting any economic damage by the stalk rot disease. Leaf blight is still common especially in early maturing maize varieties. Selection and breeding for leaf blight tolerance is a regular feature of research activities.

Harvesting Time: The crop is generally harvested at 22-25% moisture level in the grains. At this stage the physiological maturity is accomplished and black (cuticle) layer can be seen at the tip of grain. Cobs are harvested and sun-dried to bring down moisture below 15% for safe storage and shelling with shellers.

Post Harvesting Handling: Generally, post harvest losses are enormous in the developing countries. Roughly about 5% of the crop is wasted at the time of harvesting in Pakistan. For this purpose, protection at harvest is essential, as the post harvest losses may be as high as 30% or even more in some underdeveloped countries of the world. These losses can be reduced by taking care during harvesting, shelling, drying and storage. During harvesting, ears should not be lost or destroyed. After harvesting, ears should be dried properly to protect from fungus and other storage grain pests. Shelling should be done mechanically by shellers carefully so that, grains should not be spilled out and broken. In storage, insect pests and rodents damage the grains significantly. After harvesting, grain should be stored in clean and dry place. Protection against stored pests may be provided by applying 2 Agtoxin tablets/bag, after raping the punctured match boxes. All post harvest losses result in big qualitative and quantitative losses of seed, which is a main part of post harvest losses.

Natural method of drying: The ears are de-husked and are dried in the sunshine on the concrete platform or compressed soil for a few days. The ears must be protected from rainfall and heap/sacks must be turned up and down in order to provide air-circulation, which will keep the seed protected from fungus development/any other loss. Before, shelling, the undesirable ears may also be discarded.

Artificial Drying Methods: Ears are dried in special drying plants. In these plants, the ambient warm air or artificially heated air is forced through the mass of ears in special bins or drying plants. There are various methods of constructing these bins and drying plants. The smallest and simplest types are driers for small quantity of seed, i.e., breeder's seed. The air temperature should not exceed 42-43^{0}C otherwise the higher temperature would kill the germ.

The only disadvantage of artificial drying is the high cost, while the advantages are simple handling, high output and saving of manpower.

Storage: In Pakistan, 2-10% losses in storage have been reported in case of maize. However, most of the authors have reported that loss due to insects is 2.5%, on the average. Seed is not a dead entity like stones, so its storage requires proper planning. Seed respires, which produces heat and moisture; it also absorbs heat and moisture from its surrounding and this cause deterioration of the seed. Seed is also a source of food for insects, rodents and other living organisms. Therefore, the stored maize seed can never be quite as good, it will be even poorer in quality at the time of sowing. This would also have adverse effect on the maize crop.

In order to maintain its viability seed should be stored under low relative humidity and low temperature conditions, storage must be provided for 4 different situations.

a) On the experiment station:

i) Germplasm and breeders seed which may be kept for extended periods.

ii) Foundation seed which must be stored for period of 2 – 4 years.

b) With seed producers:

i) Seed held from harvest to planting.

ii) Seed that remains unsold at the end of one season and must be kept until the next season.

Each one of these situations may require a different type of storage facility. Germplasm and breeders seed must be kept in cold rooms while foundation seed can be kept in well insulated, moisture proof rooms cooled by air conditions. There are two general rules we should always keep in mind while storing seed. Firstly, for every 10^{o}F decrease in storage temperature one can double the life of the seed. Secondly, for every 1% decrease in moisture content one can double the life of the seed. If seed is to be kept viable for any length moisture contents owing to be development of harmful micro-organisms such as yeasts, moulds, and bacteria; furthermore, spontaneous heating caused by kernel respiration accelerates the deterioration process. Wet grain containing 40% moisture begins to generate heat and to release the sour odor indicative of accelerated decomposition only after 10 hour's storage at ambient temperatures of 15^{0}C and above. Accordingly, the first priority in the storage of maize grain is to condition the product so that it will be kept for a given period of time without any significant loss in quality, the costs of conditioning must be minimal yet maximal efficiency is expected.

Potential Scaling-up of Proven Technologies for SAARC Countries

Technical

1. Ridge sowing to maintain plant population & save irrigation water.
2. Use of treated seed.
3. Timely adoption of plant protection measures (weedicides, insecticides & fungicides)
4. Use of mechanical harvesting technology.

Key Policy Inputs for Improvement of Proven Technology of Maize Crop in Pakistan

1. Support price for maize produced.
2. Encourage and promote Public-Private Partnership for maize improvement and seed production.
3. Establish village based enterprises for implements, fertilizers, seeds and other inputs.

Challenges, Way Forward for Maize Research and Development in Pakistan

- Double haploid production technology in maize.
- Drought and heat tolerant germplasm of maize.
- Human resource development.

Conclusion

The planting/water conservation techniques being used in maize include Ridge Planting, Bed Planting, Flat with Line Planting and Broadcast Planting. However, Ridge Planting is the best method for getting maximum grain yield per unit area. The parameters to be considered for getting maximum grain yield in maize include plant height (cm), number of leaves per plant, leaf rolling, leaf area per plant (cm^2), ear height (cm), days to 50% tasselling, days to 50% silking, grain rows per ear, grains per row, ear length and girth (cm), 100 grain weight (g), stem girth at fourth internode, shelling percentage and grain yield (kg/ ha).

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Proven Technology for Maize Improvement through Participatory Approach in Sri Lanka

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Introduction

Sri Lanka is an island in South Asia attributed with diverse agro ecological regions (AEZs). The total geographical area is 65610 square kilometers with population of 21.2 million. Agriculture sector's contribution to GDP is 7.1%. The plantation sector i.e. tea, coffee, rubber and coconut play an important role in agriculture sector with contribution of 36.6% for agricultural GDP. The contribution of food crops (cereals, rice, vegetables, sugarcane, fruits) in agricultural GDP is 25.3% and rice is the staple cereal in Sri Lanka (Central Bank Report, 2016).

Maize is the second most important cereal crop in terms of area and production. It is mainly used in the poultry industry while a small percentage is being used for human consumption as boiled green cobs or as "Triposha or Samaposha," as a supplementary diet. Even though maize was introduced to Sri Lanka in the 16^{th} or 17^{th} century, a systematic research program on developing varieties was initiated in the 1950s.

Maize is mainly cultivated during the major rainy season (*maha* season) as a rainfed crop in the uplands. During the minor season (*yala* season) which is the dry season, maize cultivation is limited to paddy fields under supplementary irrigation. In 1995, only 4% of the total maize area was cultivated during the minor season but with increasing demand and better remuneration, the share of the cultivated area during *yala* increased to about 15% in 2010. Until 2004, maize cultivars in Sri Lanka were limited to open pollinated varieties (OPVs). The first OPV "Bhadra-1" was released in 1977. Therefore, the national productivity of maize was limited to around 1 ton per hectare until 2003. In 2004, first maize hybrid "Sampath" was released and exotic maize hybrids was also introduced. Farmers quickly realized the advantages of hybrids. Productivity gradually increased to 3.6 t/ha in 2016. At present, over 95% of the total cultivated area is planted with imported hybrids.

At present, per capital income of a Sri Lankan is US $ 3,752 in 2016 (Central Bank report 2016). With increasing per capita income, it is expected that the social needs and behaviors will change, leading to changes in food habits. The consumption of meat increased from 5.57 kg (2011) to 8.8 kg/person per year in 2016 (Poultry sector forecast, 2017). The increasing demand for meat and meat-based products will create an additional demand for animal feed. Depending on the price of other cereals such as rice, feed manufacturers used alternative cereals to replace maize. The requirement of maize as animal feed has increased over the years and it is projected to increase further with the increasing demand for poultry in the country. Further, there is a growing export market for meat products in Sri Lanka. Therefore, the demand for maize is projected to surpass 500,000 tons in 2018.

Agriculture Land Use

The 54% of total area of the Island is devoted to agricultural purpose. The rest is comprised of forest, Inland water bodies, buildings and constructions (Table 1). The 44% of the agricultural land is under paddy. The area for other food crops such as cereals, pulses, oil crops and vegetables is only 21%.

Table 1: Land use types of Sri Lanka

Land use		Extent (ha.)	Percentage
Non Agriculture Land		60,661.61	0.92
Agricultural Lands	Home Gardens	1,450,849.36	22.11
	Plantation Crops		
	Tea	229,261.63	3.49
	Rubber	207,551.75	3.16
	Coconut	295,551.75	4.50
	Paddy	922,151.29	14.05
	Other Field Crops (cereals, pulses, vegetables, oil crops)	430,205.48	6.56
Forest		1,187,728.72	18.10
Forest Plantation		63,524.90	0.97
Scrub		779,603.57	11.88
Water Bodies		488,027.86	7.44
Other (Marsh, Barren Land, Distorted Surface, Grassland, Mangrove etc.)		446,405.76	6.80
Total		**6,561,000.00**	**100.00**

Source: Department of Census Statistics; Central Bank of Sri Lanka, 2016

Area and Production Status of Maize Crop

Maize cultivation in Sri Lanka has expanded over the last several years and has become a highly commercialized venture in dry and intermediate zones. Until 2007, the cultivated extent was around 27,000 ha (Table 2). To fulfill the demand for maize of the animal feed industry, in 2005 Sri Lanka imported around 147,000 tons spending Rs. 2523 million. However, a major cultivation drive was launched to increase national maize production and to achieve self-sufficiency. As a result, compared to 2007, the area under maize increased by over 70% to 59,103 ha in 2013 and imports decreased to just 528 tons.

Table 2: Maize Cultivation Extent, Production and Productivity

Year	Extent	production	Productivity	Imports (MT)
2007	27,095	45,068	1.66	78366
2008	43,173	91,286	2.11	82488
2009	44,786	114,655	2.56	27201
2010	48,882	127,761	2.61	9570
2011	41,906	104,491	2.49	7011
2012	50,881	165,999	3.26	1004
2013	55,892	173,320	3.10	528
2014	57,525	210,886	3.67	86824
2015	60,954	230,821	3.79	67237
2016	57,094	207,025	3.63	41916

Source: Agstat 2007 -2016, Socio Economic and Planning Center, DOA

Due to limited land availability, the total cultivated area of other field crops has never increased beyond 170,000 ha and 106,000 ha during *Maha* and *Yala*, respectively. Among the districts, 55% of the maize area is in Anuradhapuraya and Monaragala, while Ampara and Badulla districts comprise about 25%. All other districts have less than 1-2% maize area. To achieve the targeted production of 400,000 tons per annum, with the present average yield of around 3.6 t/ha, the area required must increase to over 117,00 ha which is double the present area under maize.

Table 3: Average Yield, Realizable Potential (2016) and Target Realizable Potential Yield in 2017 and 2020 and Percentage Increase over Present Realizable Potential of Maize under Favorable Growing Condition in the Dry and Intermediate Zone of Sri Lanka.

Crop	Present national average yield, t/ha	Present realizable Potential yield, t/ha	Targeted realizable potential, t/ha	
			2018	2020
Maize	3.6	7.0	8.0	9.0

Source: Maize crop improvement program, Field Crops Research and Development Institute, DoA, Sri Lanka (unpublished).

Genesis of Maize Improvement Program in Sri Lanka

Maize was introduced to Sri Lanka in the 1500s-1600s. A systematic maize improvement program was initiated in 1955. Since then, exotic varieties from many countries have been evaluated, comparing them with indigenous varieties. In the 1960s the crop improvement program was concentrated more on traditional methods of variety development such as variety crosses and composites and testing exotic composites and variety crosses. Materials for testing were received from various sources such as CIMMYT, the Rockefeller Foundation and national program of other countries. The majority of the germplasm available in Sri Lanka is preserved at the Plant Genetic Resource Center (PGRC), Gannoruwa. The total number of accessions to date is around 819 and only part of the germplasm is characterized.

In the 1970s, variety evaluation experiments revealed that the variety “Thai Composite” outperformed local check variety T48. Consistent performance of Thai Composite and *Cupurico* X *Flint Compuesto* over the years has led them to be included as local checks in variety evaluation. In addition, OPVs were received from the Inter-Asian Corn Program (IACP). In 1967 maize genotypes were received from CIMMYT in the form of Experimental Variety Trials (EVTs) and Elite Varietal Trials (ELVTs). As a result, from 1968 to 1980, about 900 maize genotypes received from these institutes were tested at the Field Crops Research and Development Institute, Mahailluppallama. In 1977, an improved version of Thai Composite was released as “Bhadra-1” for general cultivation (DoA, 2003). The CIMMYT population, PozaRica *7425* was improved by half sib selection scheme and released as a new variety, “Ruwan”, in 1990 (DoA, 2003).

Subsequently, evaluation and improvement of exotic composites and development of composites locally using exotic and local germplasm had been the priority of the maize improvement program. In the

Experimental Variety Development Program, the selection criteria had been the short plant height, yield stability, wider adaptability and tolerance to rainfall pattern of the main maize growing areas *(maha***)**. Promising genotypes were selected from CIMMYT materials.

To cater to the demand of the corn flour industry, a white-grained variety, *across 7929* which recorded a yield increment of 17.9% over Bhadra-1 was released as "*Muthu*" in 1992. Maize variety *PozaRica 7931* found suitable for inter- cropping and green cob production due to earliness was released as "*Aruna*" in 1992 (Table 5).

In 1990, a program was initiated to develop inbred lines by standard methods to develop hybrids. Additional maize inbred lines received from CIMMYT and Thailand were used to develop about 200 single cross hybrids in 2000. Since 2002, hybrid seed production was commenced for promising single crosses. The selected promising single cross hybrid CML20/CML348 was releases as "*Sampath*" in 2004.

In 1998, quality protein maize (QPM) inbred lines received from CIMMYT were used to develop single cross hybrids. Adaptability trials conducted in major maize growing area revealed that CML161/CML194 showed a more than 15% yield increase over recommended hybrid *Sampath*. This hybrid was released as "MI Maize H 1" in 2013 (Kumari *et al.*, 2013).

To meet the country's demand production program was accelerated by increasing the extent under cultivation and productivity. Since 1998, to increase productivity, as a temporary measure, high-yielding exotic maize varieties, compared to locally developed hybrids and OPVs, were introduced to Sri Lanka by private sector companies. These hybrids become popular among farmers and become highly commercialized venture among dry zone farmers.

The collaborative program with CIMMYT was again redirected with signing a MOU in 2012. Several single and three-way cross hybrids were received from CIMMYT, Mexico (Table 4). The promising hybrid "CML451/CML286" was selected and released as "MI Maize Hybrid 02" in 2016 for commercial cultivation. Maize varieties developed at Field Crops Research and Development Institute, Mahailluppallama in Sri Lanka have been presented in Table 5.

Table 4: Single and Three-way Cross Hybrid Trials Received from CIMMYT

Trials received from CIMMYT from 2010	Remarks
11CHTT50 - Mexico	CML451/CML286 selected and recommended as "MI Maize Hybrid 02"
12CHTTY-A1- Mexico	
12EVT215- Mexico	Acquired inbred lines of promising hybrids
13TTWCLWQ24 - Mexico	
13TTWCYL - Mexico	
15TTWCYL - Mexico	
13SLTRIAL- 16 - India	1 promising hybrid evaluating in farmer field trials
14SLTRIAL-DT86 - India	5 promising hybrids evaluating in farmer field trials
15SLTRIAL-Entries 56 - India	17 hybrids in farmer field trials
17CAHTYT-Entries 24 - India	
17CAHTQ -Entries 30) - India	

Source: Anonymous, 2015 and 2016.

Table 5: Recommended Varieties of Maize in the Dry and Intermediate Zones of Sri Lanka.

Variety	Year	Characteristics	Pedigree
Bhadra-1	1977	Yield 4 t/ha, Seed color – orange, Days to maturity 105-110	Mass selection from Thai composite
Ruwan	1990	Yield 4 t/ha, seed color – orange, Days to maturity 105-110	Mass selection from Pozarica 7425
Muthu	1992	Yield 4 t/ha, seed color – white, Days to maturity 110-115	Selection from across 7929
Aruna	1992	Yield 4 t/ha, Days to maturity 90-100	Selection from Pozarica 7931
Sampath (hybrid)	2004	Yield 5-6 t/ha, seed color – orange, Days to maturity 105-110	CML20/CML 348

Variety	Year	Characteristics	Pedigree
MI Maize H 01 (hybrid)	2013	Yield 5.5-6.5 t/ha, seed color orange, Days to maturity 105-110	CML161/CML194
MI Maize H 02 (Hybrid)	2016	Yield 5.5-6.5 t/ha, seed color orange, Days to maturity 105-110, Moderately tolerant to drought	CML451/CML286

Source: Recommended new crop varieties, 2004, 2013 and 2016. DoA, Sri Lanka

During the past 14 years, imported maize hybrids developed by multinational companies showed promising results and were popular among maize farmers. In 2016 about 20 maize hybrids were imported for commercial cultivation (Table 6). All the exotic hybrids were evaluated for adaptability and susceptibility for common pest and diseases before recommendation (Kumari, 2015).

Table 6: List of Local Seed Importers and Names of Importing Hybrids and Their Market Share during 2016.

Local Importing company	Hybrid name	Market share, %
Agstar Seeds (Pvt) Ltd	BISI222	1.2
Ceylon Agro Industries Ltd	PAC984, PAC999, PAC339	38.8
CIC Seeds (Pvt) Ltd	NK7328 (Jet 999), NK40,	47.4
Hayleys Agro Farms (Pvt) Ltd	SA,TF	1.2
Robin Seeds	CP	3.3
Summer Field Chemicals (Pvt) Ltd	SAFA	0.2
Troseed (Pvt) Ltd	PIONEER, Dekalb (DK)	7.6
Onesh Agri (Pvt) Ltd	Baby Corn Seed	0.1
Ambewela Livestocks Co. Ltd	Corn seed (Fodder)	<0.1
Food & Agriculture Organization	Corn seed (Fodder)	<0.1
Best Seeds Co. Pvt Ltd	Sweet Corn	<0.1
Plant Seeds (Pvt) Ltd	Sweet Corn	<0.1

Source: Sea port data base 2017. National Plant Quarantine Service. DoA, Sri Lanka.

Inbred Line Development

A maize inbred line development program was initiated in 1970s; however, top crosses made using local inbred line were not successful. In 2007 around 30 inbred lines were developed from different source populations and these inbred lines were used to develop single cross hybrids. Since 2008, the maize inbred line development program has been further strengthened with those introductions from CIMMYT and local inbred lines development through second cycle inbred line development using segregating populations of exotic hybrids. At present more than 50 inbred lines are available for testing.

Maize Production Technology, Postharvest Handling, Value Addition and other Improved Technologies for Research and Development

Plant Density and Fertilizer Management: Optimum plant density recommended by DoA under rain-fed conditions for OPVs is 55555 plants/ha with spacing 60 cm x 30 cm. however under irrigated and best management condition it can be increased up to 66666 plants/ha with a spacing of 60 cm x 25cm. The fertilizer recommendation for maize under rain fed condition is 225 kg/ha of urea, 100 kg/ha of triple supper phosphate and 50 kg/ha of murate of potash. For irrigated condition, the recommended amount of urea is 265 kg/ha. Under a high density planting system with hybrids, it could be increased to 888888 plants/ha with a spacing of 75 cm x 15 cm. However, this should be under best management practices with increased fertilizer, especially urea as high as 425 kg/ha (Malaviarachchi *et at.*, 2009).

Dry zone area is characterized by an undulating terrain with moderate to high soil erosion with heavy rains. Under farmer field conditions of continuous cultivation and with soil erosion, soil fertility has decreased. To compensate for lower soil fertility, farmers apply higher doses of urea and potassium under favorable rain-fed conditions, the amount of urea applied could increase over 400 kg/ha with high density planting (740000 plants/ha) at a seed rate of 15-17 kg/ha. The increased spacing between rows to around 75 cm allowed the use of mechanical wanderers and facilitates other operations which reduce the cost of cultivation. Mechanical seeding with multi-row seeders coupled with fertilizer application is becoming popular among farmers.

Soil Conservation and Water Management: Conservation farming is a set of practices adopted for appropriate land use systems to maintain sustainable production. It minimizes the depletion of soil fertility and other natural resources, and minimizes use of high cost external inputs, and is very vital for Sri Lankan dry zone agriculture to arrest further decline in the natural resource base of the soil. More than one million hectors of rainfed dry zone faces severe land degradation. Some of these lands were earlier used for shifting cultivation referred to as "Chena" with a long fallow period, which allowed the formation of natural vegetation, deteriorated rapidly with continuous cultivation. Continuous cultivation of upland crops depleted soil fertility quickly in the dry zone. Increased pressure for cultivable lands in the dry zone, especially maize, has invaded may abandoned lands and shrubs in forest reserves. In the early stages of maize commercialization, with the increase availability of soil nutrients and organic matter in some of these virgin soils, farmers were able to achieve higher yields from hybrids even with the moderate use of urea. However, with continuous cultivation both physical and chemical properties of the soil have deteriorated and ultimately the productivity is in declining trend. Land preparation using four wheel tractors without arresting soil erosion in these areas with inherent undulating terrain and very heavy high intensity rains during the major monsoon season has led to much of the top soil being washed away, depleting soil fertility. This had let to further increase in the yield gap. To compensate the reduction of inherent soil fertility, farmers apply heavy doses of fertilizer, which is subsidized, leading to increased pollution of water bodies with heavy losses. Hence the promotion of soil conservation bunds and converting those bunds into multipurpose bunds by planting perennials such as fruit trees, green manure producing trees are crucial. Further, incorporation of sunhemp to maize fields by sowing sunhemp seeds at the same time maize is being sown and 2-3 weeks after sowing sunhemp will be incorporated to maize field (Anonymous, 2015).

The irrigation scheduling studies has been conducted to measure the irrigation water requirement for different crop growth stages based on pan evaporation. The total water requirement was estimated to be 450 mm to 475 mm during dry season. The 70%, 115% and 115% of pan evaporation is required for 1^{st}, 2^{nd} and 3^{rd} months of cropping period, respectively. This information is useful in irrigation scheduling under major irrigation schemes operation in Dry zone (Nijamudeen and Perera, 2014).

Introduction of sprinkler irrigation as an efficient irrigation method for maize cultivation has been studied and introduced to hybrid maize seed production under agro-wells based irrigation. The 60% irrigation efficiency was recorded compared to flood irrigation by adopting sprinkler system. The cost of sprinkler system for 1 hector of land is about SLRs. 450,000.00. The promotion of sprinkler irrigation among hybrid seed producing farmers was done by providing the system for free of cost by the government.

Pest and Disease Control: Disease incidences in maize were not common as earlier maize cultivation was at subsistence level. This is partially due to cultivation of maize under rain fed conditions in uplands as a mix crop or rarely as a sole crop. In 1990s large scale commercial cultivation of maize started with imported hybrid varieties but was not rigorously screened against possible pests and diseases. Thus, new diseases such as *Physoderma* brown spot, *Erwinea* stalk rot, Southern rust and Northern leaf blight are believed to have been introduced to Sri Lanka in the recent past. Sheath blight and *Erwinea* stalk rot are the presently devastating diseases.

At present following fungal and bacterial diseases are found in Sri Lanka

- Sheath blight (caused by *Rizoctonia spp.*)
- *Erwinia* stalk rot (caused by *Erwinia spp.)*
- *Physoderma* brown spot (caused by *Physoderma maydis*)
- *Helminthosporium* leaf spot (caused by *Helminthosporium orizae*)
- Southern Rust (caused by *Puccinia polysora)*

The chemical control of these diseases is not practiced yet. The integrated cultural disease management such as protective measures and control measures are practiced as follows. Preventive measures

1. Quarantine measures – exotic seed testing, restrict importing susceptible hybrids
2. Appropriate plant density
3. Reduce over use of N fertilizer
4. Application of organic fertilizer
5. Proper land preparation to facilitate drainage
6. Farmer awareness – training, visits, crop clinics

Control measures

1. Remove infected plants or plant parts at very early stage
2. Control irrigation to protect healthy fields
3. Destroy crop residues if infected
4. Under high disease pressure- crop rotation/fallowing lands

Maize Processing, Value Addition and Product Development: Processing of maize ears and separation of seeds from dried ears was done manually in the past. However, the introduction of threshing machines for rice prompted farmers to use the same machines for maize. However, this failed due to high levels of machinery breakdowns and poor separation of seed/grains. The farm mechanization Research Center of the DoA introduced a medium scale threshing machine and versions are being used by farmers in major maize growing areas. In addition, research is being done to introduce a better combine harvester for medium to small scale farmers.

In Sri Lanka, the direct use of maize grains is very rare. However, boiled green ears are consumed directly as a supplementary meal. Other processed maize products used as supplementary food are also available in the market. Maize is the major ingredient of “Thriposha” which is cereal preparation given free to pregnant and lactating mothers, and infants by the government.

Potential Scaling-up of Proven Technologies for Sri Lanka

Quality Seed Production and Scaling-up: Depending on the area under cultivation, the annual seed requirement varied between years. In 2016, the hybrid seed requirement was around 1000 tons with a value of about 1000 million rupees. In major maize growing areas about 95% of the farmers use hybrid seeds while a limited quantity is cultivated with OPVs of recommended varieties and/or with farmer saved seeds. At present, nearly the entire maize hybrid seed requirement is met by exotic hybrids (Table 7).

Table 7: Imports of Hybrid Seed to Sri Lanka

Year	Quantity of seed imported, ton
2012	1777
2013	1112
2014	1460
2015	1314
2016	1751

Source: Agstat, 2012 -2016, Socio-economic and Planning Center, DOA, Sri Lanka.

Seed production of OPVs (i.e. Ruwan and Bhadra-1) are carried out by government seed farms under the DoA and also with contract seed producing farmers. A program is now under way to produce seeds to meet 10% of the hybrid seed requirement of “MI Maize H 01” released in 2013 in collaboration with contract farmers, private seed companies and government institutes. The parental lines will be multiplied by the DoA and F_1 seeds will be produced by other organizations. The hybrid seed producing farmers were encouraged by providing parental seed for free of charge and buy back the F_1 seeds for fixed price. Further hybrid seed production technology was promoted by field demonstrations and visits, and follow up is done by extension staff.

Approaches for Enhancing Small Holder Farmers Access to Improved Technologies and Income Opportunities : Agriculture extension officers at village level disseminate technical information. Apart from that farmers have direct access to Agriculture Hot Line “1920” free of charge from any network, directly access to research institutes for technical advices. Further, the frequent crop clinics and demonstrations are done by extension staff in collaboration with researchers. The lateral distribution of good varieties through farmer participatory “Variety Adaptability Testing” programs are also going on as routing activity of the breeding program.

Incentives and Protective Measures for Maize Farmers: Farmers are encouraged to use agronomic package by providing fertilizer at subsidized rate. The promotion of use of high yielding exotic and locally developed maize hybrids is done by providing seeds at 50% of cost. The financial assistance is provided to construct multipurpose soil conservation bunds for upland maize that is vulnerable to soil erosion and land degradation. The crop insurance program is done with lower premium to help farmers to mitigate the damages caused by drought and flood.

The marketing structure for maize is mainly handled by the private sector. The competition among buyers, especially among final purchasers, is very limited. The farm gate price of maize is therefore largely determined not by market demand and supply but by other means (Table 8). However, assured market is provided for growers at the time of harvesting by regulating imports.

Table 8: Cost of Cultivation, Profit and Farm Gate Price of Maize Crop in Major Maize Growing Districts during *Yala* and *Maha* Seasons

Season*	District	Irrigated/ rain fed	Total cost Rs/Ac **	Profit Rs/Ac	Unit cost Rs/kg	Farm gate price Rs/kg
Maha 2011/2012	Anuradhapura	rain- fed	45582	9244	26.46	31.82
	Monaragala	rain- fed	42891	15397	22.9	31.12
Yala 2012	Badulla	irrigated	64261	6478	28.84	31.75
	Anuradhapura	irrigated	54073	13488	23.53	29.4
Maha 2012/2013	Anuradhapura	rain- fed	49017	6393	26.54	30
	Ampara	rain- fed	36684	6685	24.17	28.57

Season*	District	Irrigated/ rain fed	Total cost Rs/Ac **	Profit Rs/Ac	Unit cost Rs/kg	Farm gate price Rs/kg
	Monaragala	rain- fed	46767	7637	24.93	29
Yala 2013	Badulla	irrigated	62879	15136	28.21	35
	Anuradhapura	irrigated	46553	23215	21.55	32.3
Maha 2013/2014	Anuradhapura	rain- fed	45814	13941	24.3	31.7
	Ampara	rain- fed	37467	21125	20.08	31.4
	Monaragala	rain- fed	45436	15107	23.26	31
Yala 2014	Badulla	irrigated	61454	4714	33.44	36
	Anuradhapura	irrigated	52528	9166	23.2	27.25
Maha 2014/2015	Ampara	rain- fed	41840	14585	22.62	30.5
	Anuradhapura	rain- fed	50392	851	30.49	31
	Monaragala	rain- fed	46243	2109	30.6	32
Yala 2015	Badulla	irrigated	65795	1915	35.95	37
	Anuradhapura	irrigated	61554	11928	30.99	37

Source: Cost of cultivation 2012-2015, Socioeconomic and Planning center, DoA. Sri Lanla

Note: *Yala – dry season (April to August), Maha – Rainy season (October to February)

** Ac – 4000 m^2 = 1Ac US$ 1 = Rs. 146.00

Source: Cost of Cultivation, Hand book (2011/12 to 2015). Department of Agriculture, Sri Lanka

Key Policy Input for Improvement of Proven Technology of Maize Crop in Sri Lanka

Government Policies and Interventions

In the 1970's with the food production drive of the government, maize production was encouraged under protective policies, especially through import restrictions and intervention through a government purchasing mechanism. However, after 1977 through the open economy policy, changes in government intervention through import/export policies and changes to market interventions occurred. In the 1980, a major program to boost subsidiary of food crops under the USAID-funded Diversified Agriculture Research Project (DARP) and in 1986, the Mahaweli Agriculture and Rural Development Project (MARD), were implemented seeking to promote maize and other field crops cultivation in the dry zone. In 1996, the National Seed Policy and in 2003 the seed act was introduced to improve quality and to regularize the seed industry. Since, then private sector has taken over certified seed production and the importation of seeds while the government sector has been limited in the entire basic seed production process. However, policies changed with the demand for better quality seeds and at present both the private and government sectors are involved in certified seed production of all crops including maize.

The Paddy Marketing Board (PMB), established in the early 1960s, was involved in purchasing maize in the 1970s and 1980s for the government owned animal feed milling industry. However, with the introduction of the open economic policy, PMB was closed down in 1996. Thereafter the government introduced purchasing programs through Co-operative Wholesale Establishments (CWE) and Multi-Purpose Co-operative Societies (MPCS) but no evidence is available on maize marketing through these establishments. In 1999, the Central Bank of Sri Lanka introduced the forward sales contract system for maize and it is being successfully implemented.

To encourage maize cultivation to become self-sufficient in maize, several tariff and non-tariff barriers were introduced. However, these policies were changed or modified in an ad hoc manner to protect Sri Lankan farmers. In 1999, there was a 35% duty on the import of maize and in 2002, all taxes were removed. A 3% duty and a 10% surcharge were introduced in 2003 and the licensing requirement for importing maize was removed in 2003.

Government Food Production National Program (FPNP) – 2016 - 2018

The government's overall aim in agriculture is to achieve a sustainable increase in production through increasing productivity and competiveness and to become self-sufficient in major food crops, including maize. Climate and other environmental advantages and the global food crisis have improved the country's prospects to address the food security issue through the adoption of appropriate measures to develop the agriculture sector.

The government's agricultural policy seeks to realize the following multiple goals.

a) Achieving food security.
b) Ensuring higher and sustainable income for farmers.
c) Ensuring remunerative prices for agricultural produce.
d) Uninterrupted access to both local and foreign competitive markets.
e) Mechanization and expansion of area under cultivation.
f) Increase productivity through the introduction of efficient crop, nutrient and water management techniques and seeds of new high yielding varieties.

The government has identified potential areas in the country for particular crop commodities and crop zones have been identified based on agro-ecologies and soil parameters. As such, Anuradhapura and Moneragala districts have been identified as primary districts for maize cultivation. However, with the continuous increase in demand from the animal feed industry, maize cultivation would be further expanded to other dry zone districts, especially the northern districts as a rainfed crop during the major rainy season. The government will provide required facilities such as a fertilizer subsidy and a free extension system to disseminate proven technologies. Further measures such as the imposition of CESS on selected food imports, improved access to finance, value chain development and strengthening agricultural research and extension have been undertaken to protect and promote local procedures. Remunerative prices for food items including maize have been established. Fertilizer and seed subsidy schemes have been introduced and private sector's participation in agriculture is encouraged. A 50 kg bag of fertilizer (N, P and K) is subsidized to Rs.2500.00.

It is projected that it is a need to produce more feed material to animal husbandry to meet the country's meat, milk and other animal protein requirements. As such, the annual requirement for maize would further increase to 500,000 tons which is almost double the present production. This target could be successfully achieved only if the average productivity is increased to over 5 t/ha.

Challenges and Way Forward for Maize Research and Development in Sri Lanka

Challenges

Major constraints of hybrid breeding program of maize are lack of variability in available germplasm for different traits such as yield, quality, and tolerant to biotic and abiotic stresses. Further lack of trained breeders/manpower with international exposure on breeding research and novel techniques in breeding to expedite to research program. At present only way receiving germplasm is from CIMMYT. Hence locally developed hybrids could not compete with new exotic hybrids. Therefore, dependency on exotic hybrids is caused to spending of considerable amount of foreign exchange as well.

Further private sector involvement on research and seed production is lagging behind. Apart from introducing exotic hybrids and promotion of agronomic packages such as spacing and fertilizer, the private sector did not initiate breeding research yet. The farm mechanization research is needed to reduce cost of cultivation and labor shortage which now experiencing by the maize farmers. Further influence of biotic and abiotic stresses are threatened to sustain the maize productivity over the time.

Way Forward for Maize Research and Development

The long term objective of the maize research program is to develop high yielding, pest and disease tolerant/resistant, medium-duration maize varieties which are water and fertilizer efficient for favorable eco systems and high temperature and water stress-tolerant for stressed ecosystems. Further climate-smart agricultural practices with suitable agronomic and cultural management options and conservation farming systems for identified stressed ecosystems will be developed and disseminated.

Specifically, high-yielding hybrids which are tolerant to pests such as stem borers and diseases such as sheath blight and *Erwinia* stalk rot will be introduced/developed using conventional and molecular techniques for favorable ecosystems. Seed production of new varieties is encouraged through private sector involvement. Further hybrid and/or OPVs that are tolerant to biotic and especially abiotic stresses will be introduced/ developed. In addition, climate-smart crop husbandry techniques and cropping systems for different land systems in major agro-ecological zones (dry and intermediate zones) for sustainable maize farming will be introduced. Further demand-driven nutrient management techniques, production forecasting systems to regularize the maize market and pest and disease control using both cultural and chemical techniques are being studied.

Further, sustainable management options for maize using conservation agriculture techniques for efficient use of available natural resources in most vulnerable AEZ's will be identified and disseminated to increase production through increased productivity and area under cultivation. Value addition is considered as a key area targeting the local consumer and export markets.

The government is keen to develop the above technologies with the participation of both national and international scientists/institutes with the aim of achieving self-sufficiency and providing excess to the export markets. The regional collaboration with SAARC countries for research and development is timely important as maize is becoming second important cereal and highly commercialized venture in south Asia.

Conclusion

Maize is second important cereal in terms of cultivation extent and production in Sri Lanka. However, 80-85% of production used for poultry and cattle feed industry. The maize is given as the first priority crop under other field crops in research and development programs at Field crops research and Development Institute of DoA. The several OPVs and hybrids were developed in the country in collaboration with CIMMYT during last 40 years. Farmers are demanding hybrid maize seeds and 95% of maize area are under hybrid maize. The 95% of the total hybrid seed requirement is met by imported high yielding hybrids. Hence national average productivity has increased up to 3.6 t/ha. The main drawback is sustaining the productivity in maize lands due to land degradation and other abiotic and biotic stress. Therefore, government policy is to self-sufficient in maize production by increasing productivity through different strategic plans. The future focus of research is development of hybrid maize with high yield potential and giving special emphasis on stress resilience.

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Proceedings of the SAARC Regional Video conference on Scaling up of Proven Technologies for Maize based cropping systems through Participatory Approach in SAARC Countries

18 September 2017 at SAARC Agriculture Centre (SAC)
Dhaka, Bangladesh.

Jointly organized by SAARC Agriculture Centre (SAC), Dhaka, Bangladesh & International Maize and Wheat Improvement Centre (CIMMYT), Bangladesh

Background

Most of the maize in Asia is grown as a rain-fed crop, which is prone to vagaries of seasonal monsoon rains. This is clearly reflected in the productivity of maize under rain-fed systems usually less than half of the irrigated system. The erratic distribution pattern of monsoon rains results in drought or water logging at different crop growth stages, which is the main factor responsible for relatively low productivity of rain-fed maize. Due to the possibility of uncertain economic returns, farmers often hesitate to invest in costly improved variety seeds, fertilizers and other inputs, which further add to poor yields of rain-fed maize. Climate change effects are further threatening an already challenging maize mega-environment in the Asian tropics, which are identified as subject to climate change effects, with high vulnerability and low adoption capacity.

In this connection, increased production of maize in SAARC countries increase incomes and improve livelihood opportunities resulting from sustainable maize-based farming systems and thus lessening pressure on forests, hill slopes and other crops. Maize can ensure increased demands for food and food prices are stabilized at levels that are affordable for poor consumers. Farm systems are more sustainable and resilient, despite the impacts of climate, and their dependence on irrigation and increasingly expensive fertilizers is reduced. A greater proportion of women and young adults are able to engage in profitable and environmentally friendly farming by maize-based system. SAARC countries are able to compete more vigorously in export markets and ensure benefits for a wide range of actors in the value chain of maize crops. This provides opportunities and challenges to working in partnership with the CGIAR, the private sector, policy makers and other stakeholders to enhance efficiency and impact. Maize is high yielding, stress tolerant and nutritious. Sustainable Intensification of Maize-based Cropping Systems adding value for maize producers, processors and consumers in South Asia would be great socio-economic value for the improvement of livelihood of the farmers. In this scenario one day SAARC Regional Video Conference Meeting on Scaling up of Proven Technologies for improvement of Maize based cropping systems through Participatory Approach in SAARC Countries was organized at SAARC Agriculture Centre (SAC), Dhaka, Bangladesh in coordination with CIMMYT-Bangladesh with following objectives and expected outputs.

Objectives of the Meeting

1. To improve production of maize by promoting maize improvement technologies with participatory approach of farmers, stakeholders, researchers and extensionists.
2. To document and publicize the activities, outputs and programs for sharing technological advance in maize improvement program.
3. To strengthen the regional network and create conducive situations to increase co-operations among SAARC member countries.
4. Facilitation in Maize Research and Development (R&D) of proven technologies in SAARC Countries.

Methodology

The SAARC Focal point experts, involved in Maize research and development were connected through video conference facility. The country presentations had been done through fixed video instruments (Skype).

Expected outputs

1. Documentation of technologies available for improvement of maize production
2. Establishment of regional network for maize research and development
3. Recommendation of proven technologies for research and development of Maize for SAARC countries.

Inaugural session

SAARC Agriculture Centre (SAC), Dhaka, Bangladesh and International Maize and Wheat Improvement Centre (CIMMYT) Bangladesh jointly organized an expert consultation meeting through video conferencing on “Scaling-up of Proven Technologies for Maize Improvement through Participatory Approach in the South Asian Region” which was held on 18 September 2017. It was a virtual meeting and the focal persons were connected through Skype. The meeting was attended by the six focal point experts (Bangladesh, Bhutan, India, Nepal, Pakistan and Sri Lanka) from SAARC Member States.

The Inaugural session of the consultation meeting was stated with the introduction of focal points. From the beginning of the inaugural session, Dr. S.M. Bokhtiar, Director, SAC gave welcome remarks in the opening session and made thanks for the guests for attending in this meeting. Director, SAC in his welcome remarks briefed the importance of the meeting in different aspects covering the importance of maize cultivation of this region, and also gave brief about the activity of SAARC Agriculture Centre. Dr. T.P. Tiwari, Country Representative, CIMMYT-Bangladesh made opening remarks in the meeting. Dr. Tiwari highlighted the expected outcomes of the meeting in terms of maize production policy and technology transfer guidelines, food security to combat climate change in SAARC region which would be helpful within the SAARC Member States in reaching optimum production. He also mentioned that research, partnerships and training can help to build and strengthen a national agricultural research and extension services in maize and wheat for conservation Agriculture in SAARC Region through collaboration work between SAC and CIMMYT.

Dr. Pradyumna Raj Pandey, Senior Program Specialist (Crops), SAC briefed the outline of the presentation. He was explained about the importance, opportunity and prospect of maize production in this region. He mentioned that maize is one of the most important crop under rainfed condition which play a major role to improve the income of farmers and their livelihood, food security as well as conservation agriculture. One of the constraints in conventional maize crop cultivation is low productivity due to lack of awareness on package of practices and improved varieties on the basis of ecological situations. Fertilizer use is very low or with almost no use of fertilizers, pesticides and use of improved crop varieties is extremely limited. To improve productivity and production as well as income of farmers, on farm demonstration were conducted of maize crop in different clusters in collaboration with SAARC Member States. Actual and recommend package of good practices applied to the framers in On-farm demonstration viz. use of better agronomic practices, improved variety, line sowing, balanced use of fertilizers and crop protection measures resulting increase of the yield of crops satisfactory.

Technical Session-I: Country Presentations

Moderator of the technical session Dr. Dinabandhu Pandit, Senior Technical Coordinator, CIMMYT, Bangladesh highlighted the importance, challenges and scaling-up of maize program in his speech before going to detail presentation.

The session began with the presentation of Bangladeshi paper. Dr. Salahuddin Ahmed Principal Scientific Officer, Plant Breeding Division, Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur presented the paper in the meeting. He showed in his presentation, in case of production (2.76 MT) maize is the 2nd important cereal after rice and 1st in production per unit area (6.66 t/ha) which is higher than wheat (3.0 t/ha) and HYV rice (3.8 t/ha). Winter maize area and production is 0.324 MH and 2.316 MT respectively. Summer maize production is increasing gradually to 18.18% from 16.06 % of the total maize area (0.396 MH) and production (2.76 MMT) respectively. Average yield estimated is 6.66 t/ha. Most of the land of Bangladesh is moderately suitable for growing maize based on soil and climate. Moreover, Rajshahi division is the most suitable area for maize production. Dr. Salahuddin also presented the importance of maize in Bangladesh. In Bangladesh, maize demand is rising for feed of expanding poultry and fish industries. Moreover, maize is well adapted to *rabi* season and high yield with economic return is much higher than other major cereals. Maize also fits well in profitable cropping patterns, low risk of complete crop damage and versatile use (e.g. feed, food, fodder, fuel and green manure). Now Government has been more interested for maize production in case of breeding and research area. Bangladesh needs water logging, drought, lodge and bio fortified maize varieties he highlighted in his presentation. Establishment of maize based industry, capacity building of scientist, farmers and related stakeholders, policy development for exchange of germplasm and technical guidance he also emphasized in his presentation.

As a second presenter, Mr Namgay Wangdi, Senior Research Assistant, Agriculture Research and Development Center, wengkhar, Bhutan made a presentation on above topic**.** He presented that maize is second as a staple food in Bhutan. It ranks first in terms of total production. Around 20 Dzongkhags grow the maize and Contributes 49% of the food basket. Maize production area is 77,000 ac and total annual production is 77,300 mt, average national yield 2.5 t/hac and over 69 % of the household cultivate maize in Bhutan. The main challenges of maize production in Bhutan are like commercialization of maize through the promotion of hybrids in maize production with contract farming and PPP model, promotion of Community Based Seed Production for improving the quality and easy access to maize seed production of farmers, development and promotion of maize based enterprise. Bhutan needs support and recognition of maize research for adaptation of improved technologies, policy support for commercialization of maize through contract farming, improve the marketing of maize, mechanization of maize processing by putting in place a suitable milling facility for improvement of proven technology of maize in Bhutan he emphasized in his presentation.

Dr. Sujay Rakshit, Director, ICAR-Indian Institute of Maize Research**,** PAU Campus, Ludhiana, Punjab, India presented the report on maize production and technology scenario in India. In the presentation, Dr. Rakshit highlighted about the importance of maize for food security as population is increasing rapidly, arable land is decreasing, lack of water resources and climate change is bringing to new dimension to the challenge. In India, maize is 3rd most important crop and India represents 4% of global area and 2% of global production. Maize contributes 10% of national food demand. The current five yearly average areas under maize is 8.9 million ha and production is 23.0 million MT in India he highlighted in his presentation. In the presentation, he also added maize cultivation is one of the opportunities to conserve agriculture. Zero Tillage, crop residue can be used to make soil health. In India, maize production is a great opportunity in non- traditional belt for crop diversification, risk mitigation and climate change solution. The main challenges are; enhancing rate of genetic gains, climate resilient hybrids, lack of disease resistant variety, enhancing resource use efficiency, up-scaling hybrid adoption etc. showed in the presentation.

First session was completed with the presentation of Indian paper. The presentations were followed by detail and open discussion with queries. During the discussion, Dr. Sujay Rakshit, Director, ICAR-Indian Institute of Maize Research raised the question to Bangladeshi participant about physiology of maize, crop duration of yellow and white maize, irrigation time harvesting method etc. Director, SAC opined the raise question of varietal development (OP/Hybrid) and their average production per acre. Dr. Keshab Koirala, National Maize Coordinator, National Maize Research Program, Nepal emphasized the diseases of maize and disease resistant variety on maize development. Also questions come from Bhutan and Sri Lankan participants for technology sharing of maize improvement.

Technical Session-II: Country Presentation

Moderator of the session Dr. Pradyumna Raj Pandey invited the speakers for country presentations. During the session, there were three presentations from representatives of Nepal, Pakistan and Sri Lanka.

Dr. Keshab Babu Koirala, National Maize Coordinator, National Maize Research Program**,** Nepal explained the maize production scenario in Nepal. Nepal already released 29 OPVs (including two QPM) and 5 hybrids have been released. Two heat stress resilient hybrids named

CAH 151 (Rampur Hybrid 8) and CAH 153 (Rampur hybrid 10) also registered in Nepal which showed in the presentation. There were not sufficient research findings on post harvest technology but the manual handling processing is continuing in Nepal. The main challenges for maize production in Nepal are like as yield gap, limited hybrids, seed demand is increasing but supply is limited, poor human and physical resources, climate change (drought, heat and cold stress), low productivity, limited varietal option and low seed replacement rate, high cost quality seed, unavailability of required inputs when it is necessary and input cost is high. Nepal wants cooperation and collaboration among SAARC countries for maize research and development, Promotion of hybrid maize technology in potential pockets, develop stress resilient technologies to tackle climate change issues (heat, drought, cold, diseases, insects etc.), sharing of promising technologies among SAARC countries he also added.

The fourth presenter was Dr. Muhammad Yousuf, Director/National Coordinator (Cereal System), Pakistan Agricultural Research Council, Islamabad, Pakistan and made a presentation on the above subject matter. Maize is 3rd important food grain in Pakistan, it contributes 0.4% to GDP. Production is 4.9 million tons from 1.2 million Hectare and average yield is 4.5 t/ha showed in the presentation. Pakistan has many uses of maize like Noodles, Corn flour, Maize Bread, Edible oil, Plastic – Corn stocks, Biofuel –Ethanol, Herbal Supplements – Silks etc. In this presentation Dr. Yousuf also highlighted the benefit of maize production in terms of farm income generation, food security and maintain of soil health.

Ms. W.M.R. Kumari, Assistant Director of Agriculture, Field Crop Research and Development Institute, Sri Lanka explained the overall scenario of Maize production. Maize is the 2nd important cereal and annual requirement 450,000 - 500,000 mt. in Sri Lanka. Sri Lanka also giving motivation to maize production of small farmers by providing improves technologies that may contribute to access income opportunities and conservation technology for soil. The major constraints for maize cultivation are; lack of variability in available germplasm for different traits such as yield, quality, biotic and abiotic stress tolerance variety and lack of trained breeders. The challenges of maize production are strengthening the hybrid variety development program, increase the productivity of maize by using best management practices and reduce usage of agro chemicals, self sufficient in hybrid seeds, decrease dependency on exotic hybrids, reduce the cost of production by popularizing farm machinery and assurance of market for fixed farm gate price which were found in Sri Lankan presentation.

Discussion of Brainstorming Session

Moderator of the Brainstorming Session Dr Pradyumna Raj Pandey, Senior Program Specialist, SAC, Dhaka, Bangladesh highlighted that maize has great opportunity its effectiveness and positive impacts of maize research on food security, poverty reduction, gender equity, and the environment through an improved understanding of maize price developments and better targeting of new technologies, policies, strategic analysis, and institutional innovations.During discussion, many questions came from the participants. From Bangladesh part raised the issue of yield gap from experiment field of farmer's field. Moreover, lack of hybrid and quality seed for increasing maize production in South Asian region. India raised the question about planting methodology, percentage of HYV use in Sri Lanka and average yield of production. Bhutan raised the question to Bangladeshi participant about the OP variety and inbred line of Bangladesh. After the discussion of Focal Points, moderator Dr. Pandey had instructed to send the recommendations and way forwards for Proven Technology sharing of Maize in SAARC Countries through email. The major recommendations and way forward were discussed during brainstorming session and collected through emails are as follows:

Recommendations

Bangladesh

Policy issues:

- Production of hybrid seeds locally to scale up locally developed hybrids
- Subsidizing or exemption of tax for maize based industry- Starch, maize oil etc

Technical issues:

- Training of farmers and different stakeholders
- Development of stress resilient hybrids-Excess soil moisture, lodging tolerant, Drought tolerant
- Mechanization in planting, shelling, drying etc.

Bhutan

- Training of young maize staff in breeding and agronomy,
- Sharing of promising hybrids line for heat and drought tolerance
- Yearly SAARC annual work shop on Maize program in the region
- CIMMYT should play pro-active role in implementing the maize program in the SAARC region

India

- Technological intervention: Post-harvest management of weeds using Tembotrione; Identification of alternative seed hub to support hybrid seed requirement of SAARC countries; Mechanization of post-harvest handling of maize grains
- Policy issues: Establishment of SAARC Maize Working Group towards regional cooperation; Regional linking of source and supply to supplement export-import i.e. to have a on-line system for better connectivity among growers and consumers (poultry and starch industries); Popularization of value added maize products through government schemes.

Nepal

- Formation of SAARC maize working group, SAARC Trails and workshop
- Identified maize mega-environment within SAARC countries.
- Promotion of hybrid technology through licensing and sub-licensing to private partners
- Mechanization to reduce women drudgery and labor shortage

Pakistan

Technical issues:

- Ridge sowing to maintain plant population & water saving.
- Use of treated hybrid seed preferably single cross.
- Timely adoption of plant protection measure (weedicides, insecticides & fungicides)
- Use of mechanical harvesting technology.

Policy issues:

- Support price for maize produce.
- Encourage and promote Public-Private Partnership for maize improvement and seed production.
- Establish village based enterprises for implements, fertilizers, seeds and other inputs.

Sri Lanka

Technical issues:

- Mechanization of planting, mechanical weeding and harvesting to reduce the labor cost

- Promotion of soil conservation package in rain fed uplands to increase productivity of maize
- Strengthening the development of high yielding and stress resilience local maize single cross hybrids through collaboration with CIMMYT and SAARC members

Policy issues:

- Scaling up of local hybrid seed production by providing technical and physical inputs
- Encourage the private sector participation for hybrid seed production and for research

Meeting Agenda

18 September 2017 (Monday)

Inaugural Session

10:30	Welcome Remarks	Dr. S.M. Bokhtiar, Director, SAARC Agriculture Centre
10:40	Opening Remarks	Dr. T.P. Tiwari, Country Representative, CIMMYT
10:50	Outline of the presentation	Dr. Pradyumna Raj Pandey, Senior Program Specialist (Crops)

Technical Session 1: Country Presentations (Set A)

Moderator: Dr. Dinabandhu Pandit, Senior Technical Coordinator, CIMMYT, Bangladesh Rapporteur: STO and SPO, SAC, Dhaka

11:00	Country presentation (**Bangladesh**)	**Dr. Salahuddin Ahmed** Principal Scientific Officer Plant Breeding Division Bangladesh Agricultural Research Institute (BARI) Joydebpur, Gazipur-1701
11:30	Country presentation **(Bhutan)**	**Mr. Namgay Wangdi** Senior Agriculture Supervisor II, Agriculture Rural Development Centre, Department of Agriculture, Wengkhar; Ministry of Agriculture & Forests, Royal Government of **Bhutan**
12:00	Country presentation (**India)**	**Dr. Sujay Rakshit** Director ICAR-Indian Institute of Maize Research PAU Campus, Ludhiana 141 004, Punjab **India**
12:30	Plenary discussion	
12:50	Closing remarks by Moderator	
03:00	Lunch break	

Technical Session 2: Country Presentations (Set B)

Moderator: **Dr. Pradyumna Raj Pandey**, Senior Program Specialist (Crops), SAC

Rapporteur: STO and SPO, SAC, Dhaka

14:00	Country presentation **(Nepal)**	**Dr. Keshab Koirala** National Maize Coordinator National Maize Research Program Rampur, Chitwan,**Nepal**

14:30	Country presentation **(Pakistan)**	**Dr. Muhammad Yousuf** Director/National Coordinator (Cereal System) Pakistan Agricultural Research Council 20 Atta Turk Avenue, G-5/1, Islamabad, **Pakistan**
15:00	Country presentation **(Sri Lanka)**	**Ms. W. M. R. Kumari** Assistant Director of Agriculture Field Crop Research and Development Institute Mahailuppallama, **Sri Lanka**
15:30	Brain Storming and Plenary Discussion (Facilitate by Dr. Pandey)	
16:00	Closing remarks by Director, SAC	

Rapporteurs: Dr. Md. Younus Ali, STO and Ms. Fatema Nasrin Jahan, SPO (NRM), SAC, Dhaka, Bangladesh

Participant List

S. N.	Name	Position and Name of the Institution
1	Dr. Salahuddin Ahmed	Principal Scientific Officer Plant Breeding Division Bangladesh Agricultural Research Institute (BARI) Joydebpur, Gazipur-1701, **Bangladesh**
2	Mr. Namgay Wangdi	Senior Agriculture Supervisor II, Agriculture Rural Development Centre, Department of Agriculture, Wengkhar; Ministry of Agriculture & Forests, Royal Government of Bhutan, **Bhutan**
3	Dr. Sujay Rakshit	Director ICAR-Indian Institute of Maize Research PAU Campus, Ludhiana 141 004, Punjab, **India**
4	Dr. Keshab Babu Koirala	Maize Coordinator National Maize Research Program Rampur, Chitwan, **Nepal**
5	Dr. Muhammad Yousuf	Director/National Coordinator (Cereal System) Pakistan Agricultural Research Council 20 Atta Turk Avenue, G-5/1, Islamabad, **Pakistan**
6	Ms. W. M. R. Kumari	Assistant Director of Agriculture Field Crop Research and Development Institute Mahailuppallama, **Sri Lanka**
7	Dr. S.M. Bokhtiar	Director, SAARC Agriculture Centre, Dhaka, Bangladesh
8	Dr. T.P. Tiwari	Country Representative, CIMMYT- Bangladesh
9	Dr. Pradyumna Raj Pandey	Senior Program Specialist (Crops), SAARC Agriculture Centre, Dhaka, Bangladesh
10	Dr. Tayan Raj Gurung	Senior Program Specialist (NRM), SAARC Agriculture Centre, Dhaka, Bangladesh
11	Dr. WART Wickramaarachchi	Senior Program Specialist (PSPD), SAARC Agriculture Centre, Dhaka, Bangladesh

12	Dr. Shiva Shankar Giri	Senior Program Specialist (Fisheries), SAARC Agriculture Centre, Dhaka, Bangladesh
13	Dr. Dinabandhu Pandit	Senior Technical Coordinator, CIMMYT, Bangladesh
14	Dr. Md. Younus Ali	Senior Technical Officer, SAARC Agriculture Centre, Dhaka, Bangladesh
15	Ms. Fatema Nasrin Jahan	Senior Program Officer (NRM), SAARC Agriculture Centre, Dhaka, Bangladesh
16	Dr. Md. Nure Alam Siddiky	Senior Program Officer (Livestock), SAARC Agriculture Centre, Dhaka, Bangladesh

Coordinators

1. Dr. Pradyumna Raj Pandey, Senior Program Specialist (Crops), SAARC Agriculture Centre, Dhaka, Bangladesh, (E-mail: pandeypr4@gmail.com, Cell: +880-1763708514)

2. Dr. Dinabandhu Pandit, Senior Technical Coordinator, CIMMYT, Bangladesh Office, Dhaka. (Email: d.pandit@cgiar.org, Contact no:+88029896676)

Photo Gallery

Dr. SM Bokhtiar, Director, SAARC Agriculture Centre, Dhaka, Bangladesh delivering opening remarks at the Video Conference, Dr. T. P. Tiwari, Country Representative, CIMMYT- Bangladesh is also addressing the opening ceremony

Participants are interacting during video conferencing meeting

Dr. SM Bokhtiar, Director, SAARC Agriculture Centre, Dhaka, Bangladesh interacting with participants of the Video Conference

Dr. Pradyumna Raj Pandey, Coordinator of this program and Dr. Dinbandu Pandit, CIMMYT moderating the technical sessions