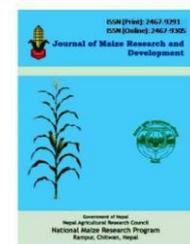


## Status and prospects of maize research in Nepal

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### ABSTRACT

Food and nutritional securities are the major threats coupled with declining factor productivity and climate change effects in Nepal. Maize being the principal food crops of the majority of the hill people and source of animal feed for ever growing livestock industries in Terai of Nepal. Despite the many efforts made to increase the maize productivity in the country, the results are not much encouraging. Many of the maize based technologies developed and recommended for the farmers to date are not fully adopted. Therefore, problem is either on technology development or on dissemination or on both. Considering the above facts, some of the innovative and modern approaches of plant breeding and crop management technologies to increase the maize yield need to be developed and disseminated. There is a need for location-specific maize production technologies, especially for lowland winter maize, marginal upland maize production system, and resource poor farmers. Research efforts can be targeted to address both yield potential and on-farm yields by reducing the impacts of abiotic and biotic constraints. Therefore, in order to streamline the future direction of maize research in Nepal, an attempt has been made in this article to highlight the present status and future prospects with few key pathways.

### INTRODUCTION

Maize is the second most important crop after rice in terms of area and production in Nepal. It is a way of life for the hill farmers of Nepal. It is a traditional crop grown for food, feed and fodder. Maize demand has been constantly growing by about 5% annually in the last decades (Sapkota and Pokhrel, 2010). Per capita maize consumption in Nepal was 98 g/person/day (Ranum *et al.*, 2014). Therefore, total quantity of maize requirement for food per year is around 2.9 million mt and the production during 2014 was 2.283million mt, hence the deficit was 0.67 million mt. The feed demand is also increasing at the rate of 11% per annum. There is a need of about 6.46 million mt. feed to run smoothly the existing poultry industries in Nepal, and about 0.5 million mt. of feed has been produced annually by the feed industries in Nepal (114, registered in NFEA). Thus, the demand for maize is also shifting from food to feed for livestock and poultry. For foods, new types of maize-based products such as soups, vegetables, edible oils are in demand. Under such circumstances, the import substitution can only be done by increasing the productivity of maize with the available shrunken land. Winter maize under rice-wheat system has been emerging as a new intervention and it can be an option to increase the maize production in Nepal. The area under winter maize in eastern and central Terai is increasing year after year.

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It is due to the increasing demand of maize for poultry feed. Similarly, winter maize yields are higher due to lower risk of pests and diseases and higher production of CHO/day/unit land among the cereals. Furthermore, the farmers are solely dependent on multinational hybrids. If the international suppliers fail to supply the hybrid seeds, farmers will be prone to leave growing maize during winter.

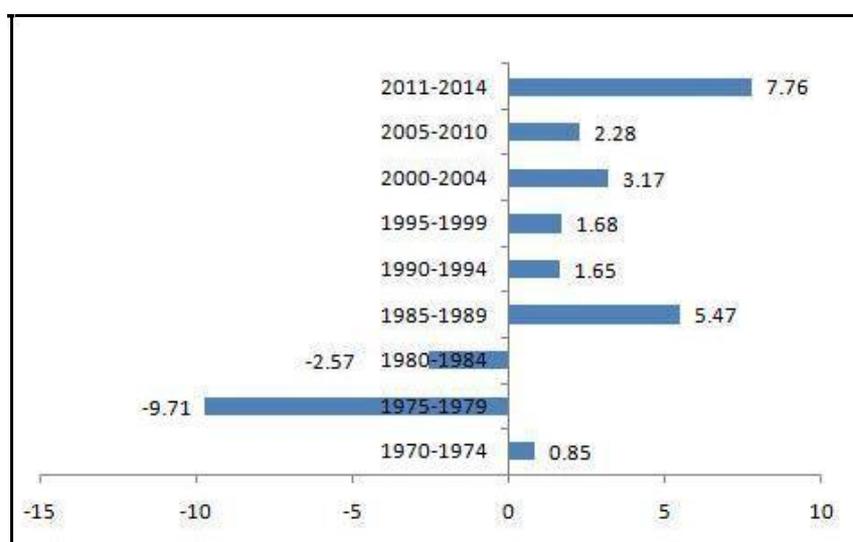
### Maize statistics: area, production and productivity

In 2005, maize was grown in 849892 ha of land and 1716042 mt of maize grain was produced and in 2014 the area and production was increased by 78869 ha and 567180 mt respectively (MOAD, 2014). The increased in maize productivity during the past decade (2005 to 2014) was only 0.439 mt/ha (Table 1). The yield increment at every five years period since 1970 to 2010 varied from negative (-9.71%) in 1975-1979 to 7.76% in 2011-2014 (Fig 1). The present yield level is quite low to fulfill the country's demand (Table 1).

Therefore, there is a big yield gap of maize in Nepal as affected by various technological and socio-economical factors (Fig 2).

**Table 1. Trend of maize area, production and productivity during 2005 to 2014, Nepal**

Particular	Year										Changes in %	
	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014		
Area	849892	850947	8704011	870166	875428	875660	906253	871387	849635	982761	9.25	
Production (mt)	1716042	1734417	1819925		1878648	1930669	1855184	2067522	2179414	1999010	2283222	33.05
Yield (mt/ha)	2019	2038	2091	2159	2205	2119	2281	2501.1	2353	2458	21.74	



**Fig 1. Trends in maize productivity at every 5 years period since 1970 to 2014 in Nepal**

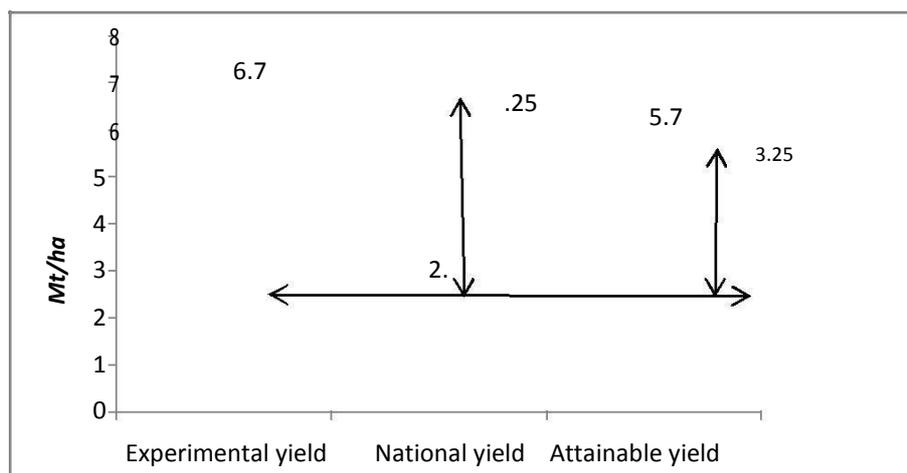


Fig 2. Yield gap of maize in Nepal (NMRP, 2014)

## Major constraints

### a. Biological

#### *Diseases and Pests in Maize Fields and Stores*

Smut (*Sphacelotheca reiliana*) and turcicum blight (*Helminthosporium turcicum*) in the eastern and midwestern/ far-western midhills and highhills; ear rot in the central/western and mid-western/far-western midhills; stalk rot in the mid-western/far-western midhills, terai, and highhills; and downy mildew (*Perona sclerospora spp.*) and leaf firing in the terai were important diseases mentioned by farmers. Banded leaf and sheath blight (*Rhizoctonia solani*) was increasing in severity and prevalence in all environments. Turcicum leaf blight is ubiquitous in hill environments and can cause severe losses if the variety does not have good genetic resistance. Similarly, gray leaf spot disease is emerging as problematic during rainy season in the hills. White grubs (*Phyllophaga spp.* and *Cyclocephala spp.*), stem borers (*Chilo partellus*), and termites (*Microtermes spp.* and *Macrotermes spp.*) were major maize field insects in all agro-ecologies. Army worms (*Spodoptera spp.*, *Mythimna spp.*) and cutworms (*Agrotis spp.* and other species) were also major problems in all agroecologies except the eastern mid hills. Blister beetle was a major problem in the central/western and mid-western/ far-western midhills and the terai, and field cricket a serious pest in the eastern and mid-western/far western mid-hills and high hills. Aphid (*Rhopalosiphum spp.*), locust, red ant, and tassel beetle were also reported by farmers. Weevils (*Sitophilus spp.*) and Angoumois grain moth (*Sitotroga cerealella*) were major problems in stored grain (Paudyal *et al.*, 2001) throughout the country.

## **b. Management**

### **■ *Soil fertility***

Among important recent changes are a reduction in livestock numbers, forest degradation, and reduced availability of labor, development of community forest and stall-feeding of cattle led to reduction in amount of manure (Turton *et al.*, 1995). The reasons for low use of chemical fertilizer included high cost, non-availability at key times and a lack of knowledge of their use. There are no updated recommendation on the doses of fertilizer for high yielding hybrids, winter, spring and summer season, rainfed and irrigated maize.

### **■ *Plant population at harvest***

One factor that contributes to low system productivity is faulty thinning practices that lead to sub-optimal plant populations at harvest. However, information on optimal plant populations is lacking for maize-millet systems in these regions (Karki *et al.*, 2014). Farmers generally plant higher seed rates and keep the higher densities of plant (92000) during vegetative growth stage and later on reduce up to 30,000 plants per hectare at harvest. The recommended plant density of 53,333/ha seems quite low in case of hybrid and spring maize. Therefore, there is a need to recommend the appropriate plant population for different seasons, practices and varieties.

### **■ *Weed infestation***

Weed cause major yield losses worldwide with an average of 12.8 % despite weed control applications and 29.2% in the case of no weed control (Oerke and Steiner, 1996). The loss caused by weed in maize ranges 40-70% (Mandal, 2000) and yield loss depend on type of weed flora and its severity. At ARS Pakhribas (eastern mid hill of Nepal) experimental result showed weedy environment resulted yield reduction up to 70% in maize (Mishra, 2004). None of the weed management practices are being adopted by farmers except manual weeding in maize.

### **■ *Seed***

In 2009, seed replacement rate of rice, maize and wheat was: 9 percent, 7 percent, and 9 percent, respectively indicating that over 90 percent of the required seed of major cereals was supplied by the informal sector. For self pollinated crops recommend replacement rate is 25 percent. Likewise, for cross pollinated crops, the replacement rate is 33 percent and for hybrids it is 100 percent (SQCC, 2013). Of the total requirements of the cereal crop seeds, contribution of the formal sector is less than 10% and quality is a constraint to productivity. Large volume of low quality hybrid and other seeds are imported from India and distributed to the farmers through agrovets, especially in the bordering districts causing occasional crop failure in the past (MOAD, 2012). Please see the SRR for different crops in seed vision 2025.

■

### ***Water management***

The total irrigated area in Nepal is only about 1331521 ha (MOAD, 2014). More than two thirds of the maize is produced in the mid hills and high hills during summer season and is mostly grown under rainfed condition. Delay in monsoon during planting, uneven distribution of rainfall and prolonged drought during crop season may affect the crop yield adversely. Water stress due to drought is probably the most significant abiotic factor limiting plant and also crop growth and development (Khalilli *et al.*, 2013). The very limited area under winter and spring maize in Terai is irrigated.

### ***c. Socio-economic***

Maize is predominantly grown in the hills and the farm sizes are also quite smaller compared to Terai region. Maize farming is therefore considered as subsistence farming in Nepal. It is regarded as a staple food of hill people. Staple commodities such as rice, wheat, potato and vegetables have higher commercialization rates (30-50%) than maize and fruits (15-25%) (ADS, 2014). The productivity is adversely affected by the shortage of agricultural labor (Joshi *et al.*, 2012). Due to an inadequate policy intervention for prioritization of agriculture research, NARC, is suffering from inadequate operational budget as a consequence maize research is also being affected.

### **NMRP and its limitations**

NMRP have modest facilities of land for research and seed production, disciplinary and multidisciplinary research projects funded by NARC, some scientific and technical staffs, and laboratories. It also works in collaboration with CIMMYT and ICRISAT, the international CGIAR organizations. In particular, NMRP is incessantly suffering from inadequate research funds, inadequate and no fixed term research staffs, lack of motivational schemes for the research staffs including exposure visits and training, poor technology delivery mechanisms, and inadequate system based researches. Disciplinary laboratories like soil, seed, entomology, plant pathology, plant breeding and agri-mechanization are not in full operation.

### **Opportunities**

There are tremendous opportunities to increase the maize production there by narrowing down the wider yield gap and horizontal expansion in winter season. Although maize yields increased slightly (0.5% per annum), the present level (2.458 mt/ha) has not kept pace with the rapid growth of the population (1.35 per annum). Poultry industries need about 664,000 mt of feed annually in the country where maize is a major source of it. Maize demand is increasing at the rate of 11% per annum in Nepal. To fulfill the growing demand of milk, meat and meat productions, we are importing about 45% of maize to be used for feed from India. While the import of food items is reduced, the only option we have is to increase the production through vertical and horizontal expansion of agricultural commodities. Under such condition, maize can play the role of economic engine of the country due to maize being a high yielding cereal; its area in Terai can be expanded during winter to feed the people and livestock. Development of non-conventional hybrids for short-term and conventional hybrids for long-term is the best alternative to increase production and productivity of maize in Nepal (Gurung *et al.*, 2011). Furthermore, the special purpose maize like quality protein maize, sweet corn, baby corn and pop corn can also be grown in accessible areas to substitute the imports.

### **Emerging issues in maize production**

The conventional maize production system needs to be converted into modern, resource use efficient and climate smart under the pretext of stagnant productivity as a result of limited area expansion, low yield potential of the existing genotypes, imported hybrid seed, declining

soil fertility, and emergence of new pest species, labor and water. Therefore, the research should focus on utilizing the latest tools of plant breeding for the development of stress resilient maize genotypes, hybrid seed production effort, climate smart, and resource conserving agro-techniques like conservation agriculture.

## Key recommendations

### 1. Varietal:

Production domain	Recommended varieties
High hills (>1500 m. asl)	Ganesh-1 and Ganesh-2
Mid hills (>1000 m. asl)	Mankamana-1, 2,3,4,5 and 6, Deuti, Sitala, Khumal Hybrid 2
Foot hills (Spring maize)	Rampur composite, Arun-1, Arun-2, Arun-3 and Arun-4, Arun-6
Terai/foot hills	Rampur composite
Terai (Winter maize)	Rampur hybrid-2 and Rampur composite

Promising NMRP hybrids: RML-32/RML-17, RML-4/RML-17, RML-86/RML-96, RML-95/RML-96.

### 2. Crop management

- No tillage with retention of previous crop residue i.e. conservation tillage (CT) under rice-maize system found superior in terms of grain yields of respective crops and their system yields, soil nutrient status (soil organic matter, nitrogen, phosphorus and potassium), cost of cultivation and hence net return, and non-lodging plants over the farmer's tillage practice of conventional tillage without the crop residue (FP). Tillage methods and residue levels affected the soil organic matter (SOM %) after the harvest of the crop. NT had the higher SOM of 2.96% compared to conventional tillage methods (2.953). Similarly, residue kept plot had higher (3.194%) SOM over residue removed (2.724). Conservation tillage in maize reduced the impact of drought by lowering soil temperature and surface evaporation, hence increased grain yield.
- In case of conservation tillage in maize, Atrazine herbicide (pre-emergence) application of Atrazine (50%WP) @ 1.5kg ai./ha within 24 hours of planting and in case of no tilled dry direct seeding of rice, Pendimethalin 30% EC @ 6ml/litre of water i.e 550 litres/ha within 48 hours of direct seeding found profitable.  
Planting geometries of 60cm between rows and 25cm between plants for hybrids found suitable in Terai.
- Tank mixture of Atrazine and Glyphosate (Atrazine @ 0.75kg a.i./ha + Glyphosate @2.5 ml/litre of water) or Atrazine (Atrazine @1.5kg a.i./ha as pre emergence) + one hand weeding at 40 days after seeding during spring season maize found better for higher grain yield and net economic return in Terai, Nepal.

- Nitrogen application @ of 180 kg N/ha in three splits (10% at planting, 30% at five leaf stage, 30% at 10 leaf stage and 30% at tasseling resulted the significantly higher grain yield of maize. Cultivation of winter maize practice and Best time of planting for winter maize was last fortnight of September and for spring it was mid February in uplands of Terai.
- For both tilled and no tilled condition, Chinese maize planter that drills the single seed per hill with 100% seed drilling efficiency found suitable for Terai and flat lands.

### ***3. Plant protection***

- For Gray leaf spot (GLS) disease the resistant/tolerant varieties are; Manakamana-3, Manakamana-5, Manakamana-6 (for mid-hills) & Ganesh-1 & Ganesh-2 for high hills Rampur Composite (Thai Comp. × Suwan-1) & Sarlahi Seto (Philippines DMR-2)-released in 1975 for Downy mildew resistant.
- For head smut- Tilt (propiconazole) or Bayleton (triademeform) @ 2 g/kg seed has been found effective for the control of disease
- Seed treatment with Apron 35 SD (metalaxyl) @ 3 gm a.i./kg seed was found most effective for the control of downy mildew
- At Chitwan, early planting prior to 14<sup>th</sup> of May resulted in lighter borer infestation and less subsequent injury from the maize stem borer, than plantings later in the season.
- For maize stem borer management, a commercial mixture of Chloropyriphos 50% and Cypermethrin 5% spray performed better as compare to Confidor 200SL and Furadan 3G whorl placement.
- Maize grains treated with 5% dust of malathion and 2-3 tables of Aluminium phosphide (Celphos) per metric ton found effective to protect against storage pests. In the case of botanicals, Bojho (20 gm/Kg seed) found effective control to maize weevil, where the infestation was only 2.25% during the period of nine months of storage. Furthermore, Neem kernel seed powder @10 g/kg and timur @4g/kg of maize grain and Super grain bag® was found free from storage insect pests up to 6 months.

### ***4. Soil fertility management***

- To date general recommendation of fertilizer for maize in Nepal is 120:60:40 NP<sub>2</sub>O<sub>5</sub>K<sub>2</sub>O kg /ha. For spring and summer season maize the recommended doses of Nitrogenous fertilizer can be applied in splits i.e at 30, 45 and 60 days after seeding for the higher grain yield.
- Maize hybrids produced the higher grain yield with 200:60:40 kg NPK/ha during winter in Terai.
- Application of 180: 90: 60 N, P<sub>2</sub>O<sub>5</sub> and K<sub>2</sub>O plus FYM 10 t/ha for full season maize produced the higher grain yield thereby higher net return.
- Incorporation of Sun hemp as green manure @ 7 t/ha of dry biomass within two months of sowing produced the good yield of winter maize and enhanced the soil nitrogen status.

### ***5. Source seed production***

- Around 36000 kg of source seed (breeder, foundation and improved) is produced annually at NMRP and distributed across the country for further seed multiplication.
- Similarly, we produce 29000, 5000 and 1700 kg of foundation seed of rice, wheat and sun hemp and distribute to the various farmer's groups for further seed production.

## Research priority

To alleviate the constraints of maize production, both varietal development and crop management research need to be implemented in an integrated approach. There is a need for location-specific maize production technologies, especially for lowland winter maize, marginal upland maize production system, and resource poor farmers. Research efforts can be targeted to address both yield potential and on-farm yields by reducing the impacts of abiotic and biotic constraints.

### In order to address the aforementioned problems the following actions need to be taken:

1. Germplasm collection, exchange, evaluation and utilization
2. Development of stress (drought, heat, cold , low nutrient and high density ) resilient high yielding hybrids and open pollinated varieties of maize for different production ecologies
3. Long term research to develop the improved pest resistant germplasm that is adapted to nutrient deficiencies and other stresses need to be enacted
4. Application of modern tools of breeding like Marker-Assisted and Genomics for the fast track and precision breeding program in collaboration with CIMMYT and other concerned organizations
5. Low cost resource conserving production technologies
6. Source seed production and distribution system throughout the country
7. Development of quality protein maize for nutritional enhancement
8. Bridging the technology generation and delivery system through outreach research program
9. Collaboration with international CGIAR organizations and multinational companies
10. Strengthen the public-private partnership for technology generation and dissemination

### Maize research areas

1. Variety development
2. Soil fertility management and agronomy
3. Plant pathology and entomology
4. Seed production technology
5. Technology dissemination
  - Technology verification in farmer's field
  - Periodic technical brochure publication
  - Training for Resource Person of Development Agencies
  - Source seed supply
  - Updating the NMRP websites (For farmers)

### Capacity building

- Technical exposure (short term training and visit) to research Scientists is necessary.
- International linkage for seed materials and technical backstopping
- Strengthening scientific research team of NMRP breeding unit
- By 2020, at least two more centers of maize research one in low to mid, and another in high hills should be established.

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