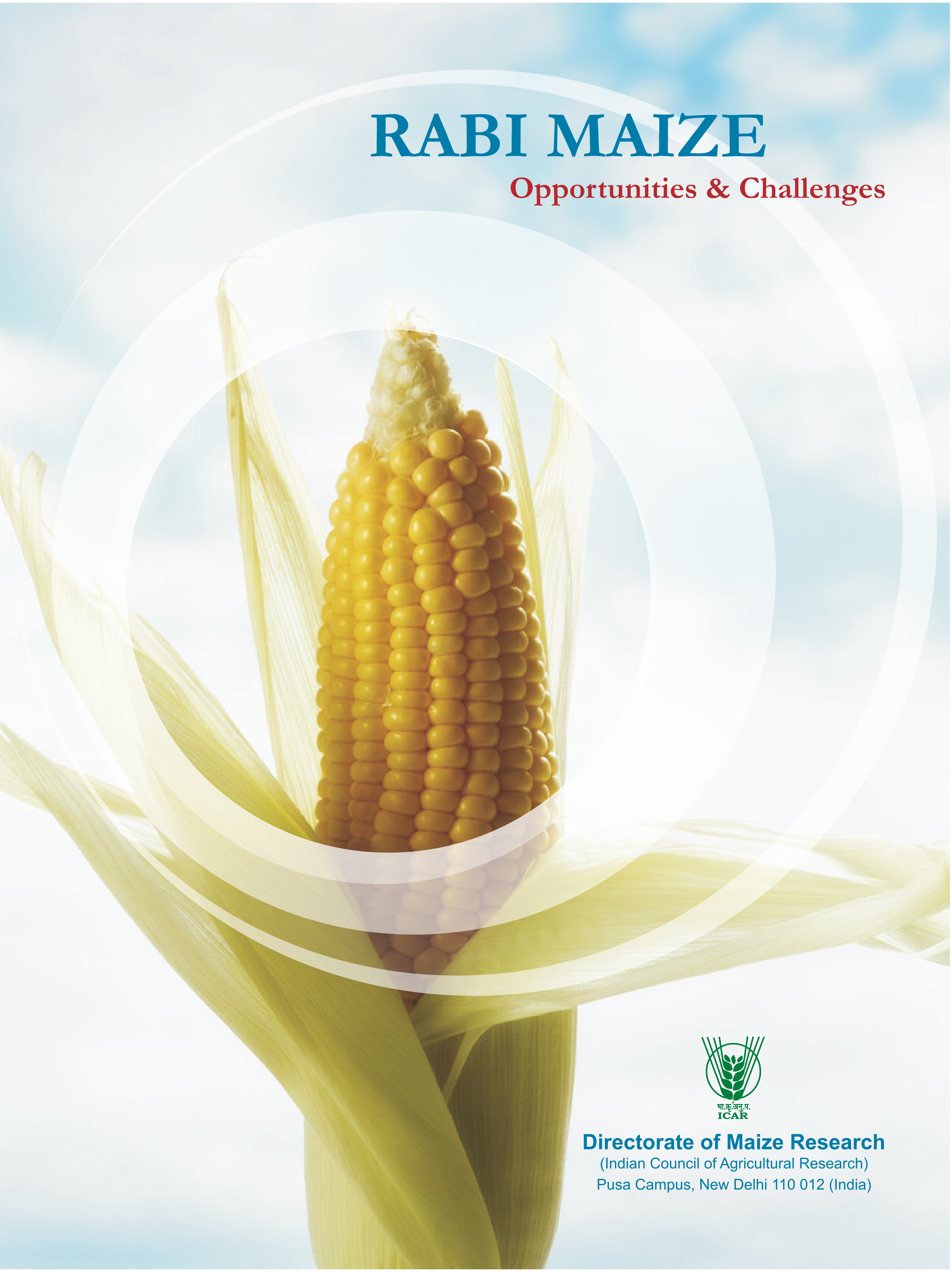
RABI MAIZE

Opportunities & Challenges



भा.कृ.अनु.प.
ICAR

Directorate of Maize Research
(Indian Council of Agricultural Research)
Pusa Campus, New Delhi 110 012 (India)

RABI MAIZE
Opportunities & Challenges

Nirupma Singh, R.Ambika Rajendran,
Meena Shekhar, S.L. Jat, Ramesh Kumar & R.Sai Kumar

भा.कृ.अनु.प.
ICAR

DIRECTORATE OF MAIZE RESEARCH
(INDIAN COUNCIL OF AGRICULTURAL RESEARCH)

PUSA CAMPUS, NEW DELHI -110 012 (INDIA)
Website: www.maizeindia.org; email:pdmaize@gmail.com
Phone: 011-25841805, 25842372; Fax: 011-25848195

Correct citation:
Nirupma Singh, R.Ambika Rajendran, Meena Shekhar, S.L. Jat, Ramesh Kumar & R.Sai Kumar. Rabi Maize Opportunities Challenges, Directorate of Maize Research, Pusa Campus, New Delhi -110 012, Technical Bulletin, No. 9: 32 p.

Printed:
2012

Published by:
Director,
Directorate of Maize Research
Pusa Campus, New Delhi-110 012 (India)
Ph: 91-11-25841805, 25842372, 25849725 FAX: 91-11-25848195
Email: pdmaize@gmail.com

Printed by:
Alpha Printographics (India)
Mobile : 9811199620, 9999039940

PREFACE

Ever growing cereals demand due to increasing population and the rising incomes with the consequent growth in meat and poultry consumption has necessitated for increasing area under maize cultivation. Introduction of high productivity maize crop is worth exploring for enhancing the food production. The ability of the maize crop to grow in different seasons and high productivity of *Rabi*/winter and *Spring* maize give it added advantages for inclusion in the cropping system as demand for more food grows. The *Spring* and *Rabi* maize are gaining popularity among farmers and multinationals because of higher yield potential and assured irrigation facilities. The success of *Rabi*/winter maize is due to sunny days, long growing season, dry and cool temperatures which are more suitable to the crop and less for the pest. Inclusion of maize in rice-wheat growing areas is a useful proposition. Ongoing efforts with alternative crop establishment methods and cropping systems proved successful. Resource use efficiency can be improved and nutritional and income security can be achieved with little more efforts in solving some of the challenges ahead. It needs a change in mind-set of farmers towards the way the crops are raised and it might call for radical changes which are possible through linking research and farmers in a harmonious way. This technical bulletin has been prepared with a view that the farming and scientific community gets an insight in overall production technologies for *Rabi* maize. The bulletin covers all aspects of the *Rabi* maize cultivation, i.e. selection of suitable cultivars, its production technologies, breeding opportunities and challenges ahead. It is hoped that this publication will be of great help to farmers, scientists and extension workers in filling the gap between the demand and supply of food grain production.

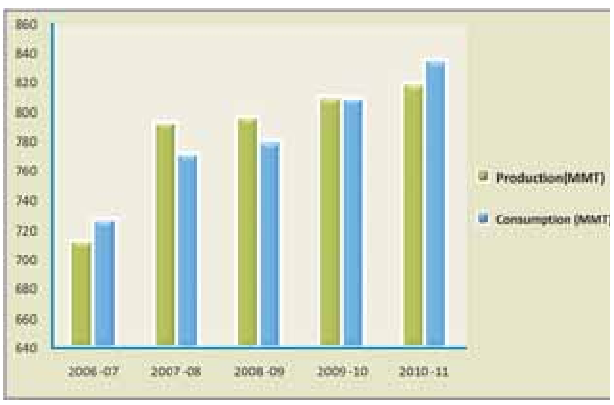
Authors

CONTENTS

RABI MAIZE

INDIAN CORN GROWERS ARE TAKING ON NEW ROLES. AS TECHNOLOGY AND GLOBALIZATION EVOLVES, OUR FARMING OPERATIONS DO,TOO. MEETING DEMAND, IMPROVING PROCESSES, EVOLING NEW PRODUCTION TECHNOLOGIES AND PROTECTING THE ENVIRONMENT ARE ALL WHAT MAKES MODERN CORN GROWING INDUSTRY AND EXCITING OPPORTUNITY TODAY.

Maize (*Zea mays* L.) is an important cereal crop in world after wheat and rice. The importance of maize lies in its wide industrial applications besides serving as human food and animal feed. It is the most versatile crop with wider adaptability in varied agro-ecologies and has highest genetic yield potential among the food grain crops. As the demand for maize is growing globally (Figure 1) due to its multiple uses for food, feed and industrial sectors, we need to produce more from same or even less resources. New production technologies offer great promise for increasing productivity to meet the growing demands of world consumers. For decades, corn growers have worked for continuous improvement and greater efficiency.



Source : USDA

Figure 1. World Maize Production and Consumption(MMT), 2006 to 2011

Maize is called 'queen of cereal' as it is grown 1throughout the year due to its photo-thermo-insensitive character and highest genetic yield potential among the cereals. In India, maize is cultivated throughout the year in most of states of the country for various purposes including grain, feed, fodder, green cobs, sweet corn, baby corn, pop corn and industrial products. Corn area, production and productivity in India has shown a steady upward trend in recent years (Figure 2).

In India, current consumption pattern of maize is poultry, pig, fish feed 52%, human consumption 24%, cattle feed and starch 11% and seed and brewery industry 1% (Figure 3).

In recent years, the maize production has significantly increased, which is largely associated with significant genetic enhancement from the area of open pollinated varieties, composites breeding to double and three way hybrids and recent development in single cross hybrids. However with dramatic increase of maize demand in developing world, including India the current trend appears unable to keep pace. The option of further increasing the maize area is limited. In India, the area of maize is sticking to around 6-7 million hectare since last three decades, and the overall increase in maize is realized largely from increasing productivity in favourable ecologies. However, the trend of genetic gain in favourable environment seems unable to meet the fast growing demand of maize in the country. Further, viable option is to reduce the available yield gaps in less favourable environment through genetic enhancement of tolerance to biotic and abiotic stress prevalent in tropics and development of

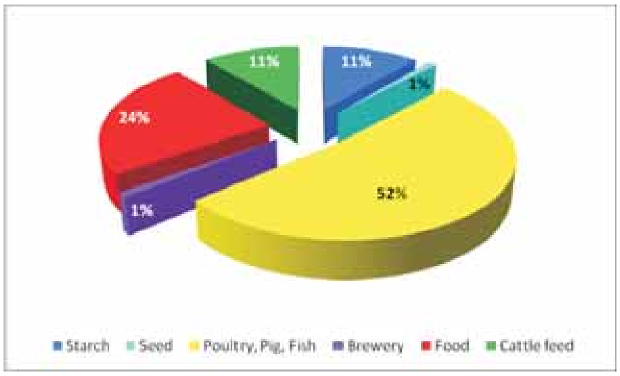


Figure 3. Consumption pattern of maize in India

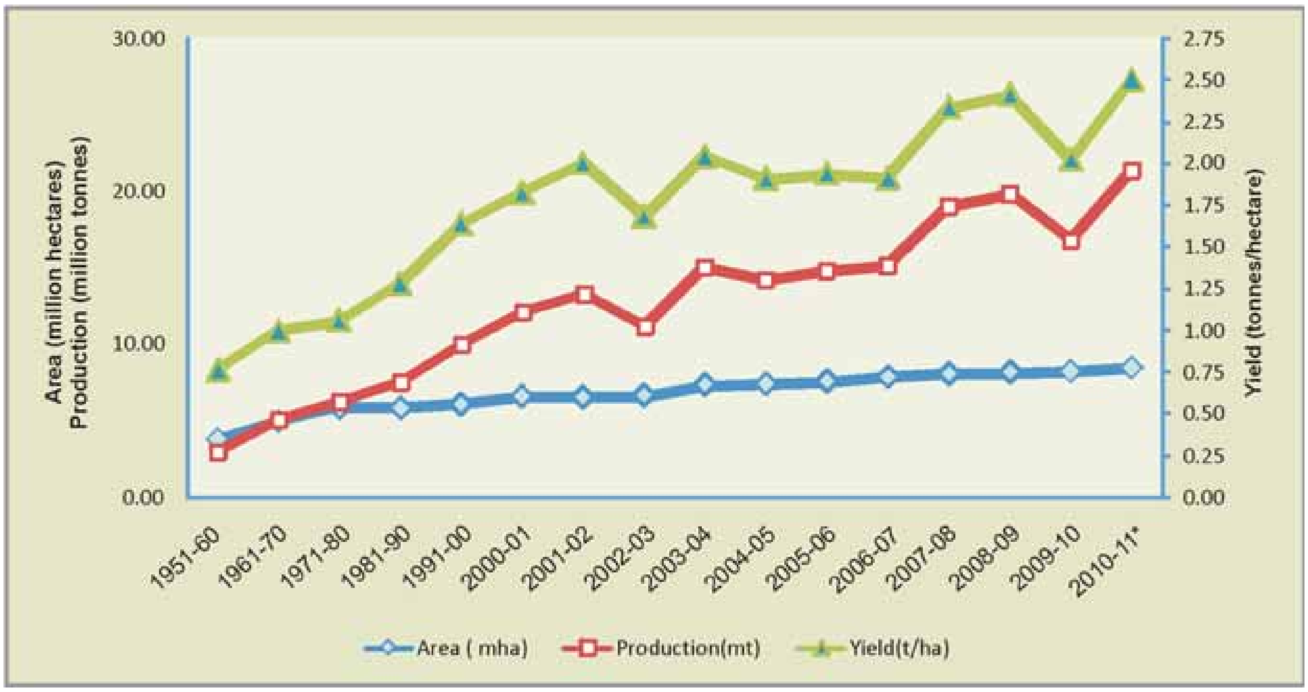


Figure 2. All India decadal growth of Area, Production and Yield of Maize

Source : DACNET

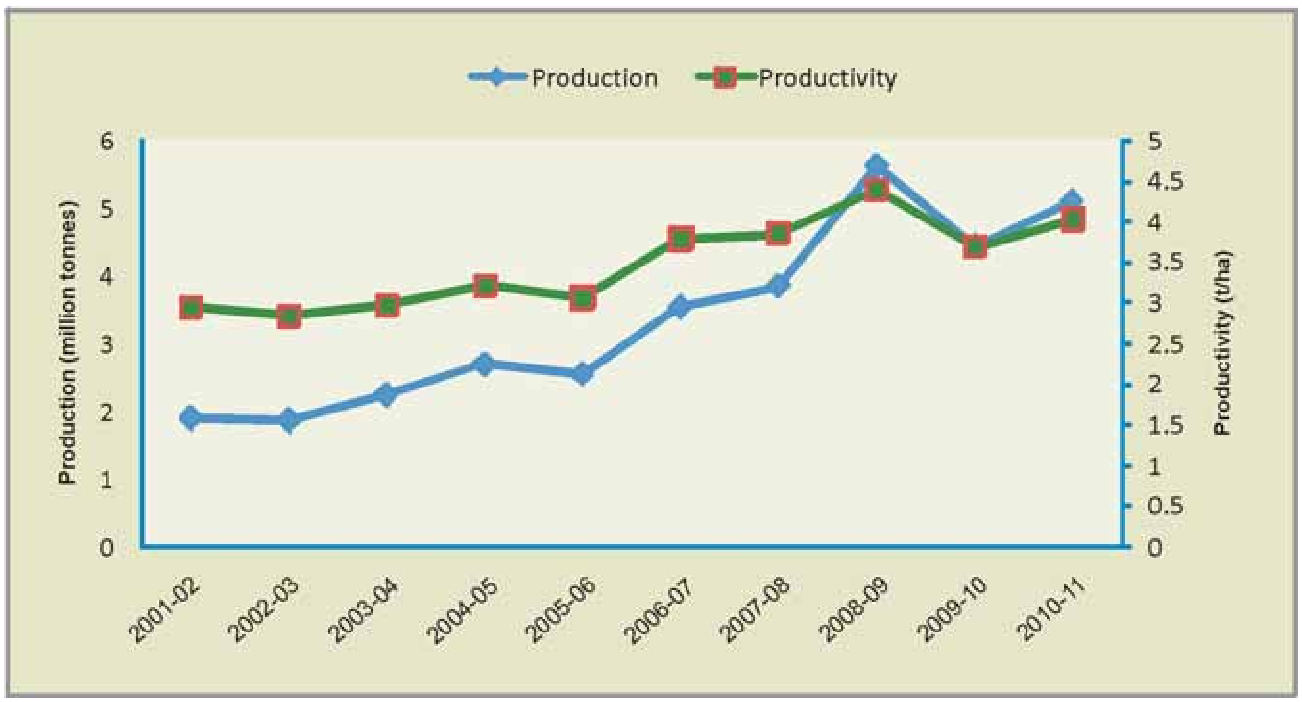
improved crop management technology for such ecologies.

There are three distinct seasons for the cultivation of maize in India : *Kharif* , *Rabi* in Peninsular India and Bihar, and *Spring* in northern India. Maize is predominately a *Kharif* season crop but in past few year *Rabi* maize has gained a significant place in total maize production in India (Figure 4).

Rabi maize is grown on an area of 1.2 million ha with the grain production of 5.08million tonnes, with an average productivity of 4.00tha^{-1} (DACNET, 2012). The predominant Rabi maize growing states are Andhra Pradesh (45.5%), Bihar (20.1%), TamilNadu (9.3%), Karnataka(8.5%), Maharastra (7.7%), West Bengal (5.3%) (Figure 5).

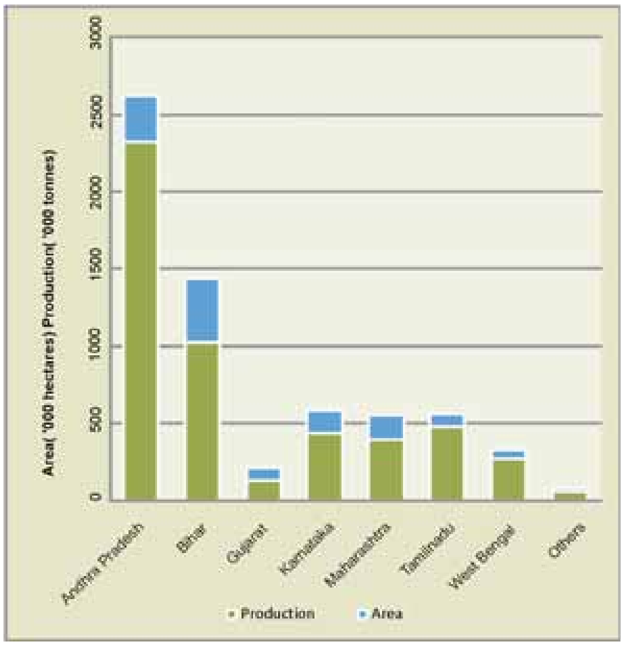
It has emerged as an important crop in the non-traditional season and non-traditional areas. Cultivation during winter is becoming a common in Peninsular India (Andhra Pradesh, Karnataka and Tamil Nadu), as well as in the north-eastern plains. Andhra Pradesh, Bihar and Tamilnadu are the three largest maize producing states with 2.322, 1.02 and 0.47 million tons respectively closely followed by Karnataka, Maharashtra and West Bengal.

Cultivation of maize in winter season started in mid 60s in some pockets of Bihar and South India. Yield obtained during this season is invariably higher (>6 t/ha) than the *Kharif* season yield (2-2.5 t/ha.) due to long duration of growth and least infestation of pests and diseases. In Bihar, maize can be taken up in all the three seasons. In recent years, significant changes have occurred in maize production and utilization due to increasing commercial orientation of this crop and rising demand for diversified end users, especially for feed and industrial uses. A sizable number of districts (110 districts), in the states of Andhra Pradesh, Karnataka, Bihar, Maharashtra, Uttar Pradesh, Madhya Pradesh, West Bengal, Orissa, Gujarat, Chhattisgarh and Tamil Nadu have potential for growing winter maize.



Source : DACNET

Figure 4. Increasing trend of Rabi maize Production and Productivity in India, 2001 to 2011



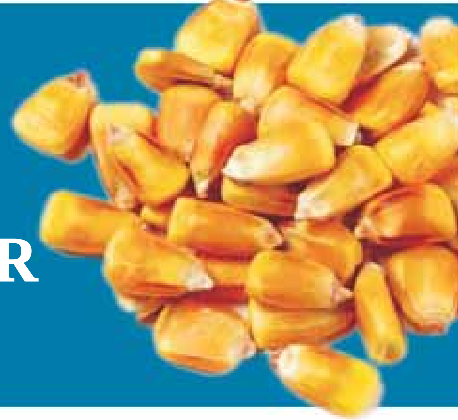
Source : DACNET

Figure 5. Area and Production of *Rabi* maize in different states of India

Heralding *Rabi* (Winter) Maize Revolution in India

Maize crop in India is in general grown in *Kharif* (June to October) season which coincides with rainy season. It is susceptible to both less and access water and results in lower production in the country. In order to enhance production of this crop a collaborative project to introduce maize hybrids in India was taken up in collaboration with Dr. L M Humphrey, Agriculture advisor to the Technical Cooperation of Mission of USA. Double cross hybrids Texas26, Texas32 and Dixie11 introduced under this project from USA in the year 1959, were grown on experimental basis in Bihar state during *Kharif* season. These hybrids could not yield up to the expectation. The reason for failure in obtaining good yield was occurrence of heavy rainfall during the crop period which is a usual phenomenon of *Kharif* season. In order to protect crop from heavy rainfall, maize inbred, single cross hybrids and double cross hybrids were grown in *Rabi* season first time on farmers fields in Bihar in the year 1961.The results were quite encouraging as the crop was free from incidence of insects, pests and diseases in addition to higher yield above the expectation compared to *Kharif* maize with the opening up of new vista of *Rabi* maize in the country. This experience encouraged in taking up of large scale testing of hybrids through series of multilocation trials and also the beginning of finding out suitable agronomic practices for exploiting yield potential of these hybrids. Keeping in view the opportunities in *Rabi* season, multipronged strategies were adopted such as hybrid seed production along with farmer's field demonstrations resulted in heralding maize revolution in Bihar. The *Rabi* maize in Bihar state is occupying 0.412 million hectare area out of a total area of 0.645 million hectare during 2010-11. This indicates the acceptance of *Rab*i maize technology by farmers of this state by clear cut comparative advantage over *Kharif* maize due to low incidence of diseases and insects-pests as well as slow growth of weeds. These factors singly and in combination favoured the adoption of *Rabi* maize cultivation in Bihar. Later it caught the attention of other states like Andhra Pradesh, West Bengal, Uttar Pradesh, Madhya Pradesh, Tamil Nadu, Karnataka, Punjab, etc., where it is being grown successfully now.

CONTRIBUTING FACTORS FOR HIGH YIELD IN *RABI* MAIZE



Though the crop favourably responds to better crop management both in *Kharif* and *Rabi* season, the erratic rainfall pattern of the south-west monsoon comes in the way of timely field operations of *Kharif* season. In absence of any major environmental impediments in *Rabi*, the desired field operations can be planned and executed at the most desired time. Moreover, the various environmental factors, including absence of any major disease and insect-pest in this season, helps in realizing better profits from every additional unit of monetary inputs. Some of the important factors favouring maize cultivation in *Rabi* are briefly discussed below:

Better water management

In absence of erratic rainfall, the crop during *Rabi* season does not suffer from waterlogging, hence damage from pre-flowering stalk rots is less. As there is no leaching of fertilizers, their utilization is maximum leading to high yield. The important advantage is the possibility of undertaking various field operations at the most desired time. The *Rabi* crop does not suffer from overcast sky which is a regular phenomenon during *Kharif* season.

Mild and favourable temperature

Maize plants in *Rabi* season tend to be more efficient in view of lower photo respiration losses due to lower night temperatures as well as larger leaf surface for effective photosynthetic activities. The other advantage in *Rabi* season is availability of 7-9 or more hours of sunshine against 3-5 hours in *Kharif* crop season due to cloudiness. Moreover, the longer growing duration of the crop helps further raise in yield levels.

Better response to macronutrients

In view of more favourable growing conditions, response to application of nitrogen and other nutrients is better in *Rabi* than *Kharif* season. The losses during *Rabi* can be checked effectively through appropriate soil and water management practices. With better response from every unit of fertilizers, which is the major component of cultivation cost, it is possible to reduce the production cost during this season.

Less incidence of diseases and insect-pests

Due to low temperature and humidity in *Rabi* season, level of infection or infestation by various diseases and insect pests is quite low, resulting in higher yields.

Better plant stand

Because of better soil and water management and less damage from diseases and pest, establishment of desired plant population density can be assured in *Rabi* season.

Better weed management

In *Kharif*, weeds pose a major problem, particularly in years when continuous rain occurs, which fail to provide adequate opportunity for manual weeding. In *Rabi* season, due to effective water management and low temperature, weeds can be controlled effectively. This indirectly helps in improving the fertilizer- use efficiency.

PACKAGE OF PRACTICES FOR INCREASING PRODUCTIVITY

1. Choice of cultivars

The success and the level of profit from *Rabi* crop depend to a great extent on the choice of maize hybrid/composite to be grown. Farmers should therefore be encouraged to sow only high yielding hybrids suitable for *Rabi* season. The use of F_1 hybrid seed is essential for realizing high yield. The recommended hybrids, in general, have given 60% to 80% grain yield than the local varieties in most of the evaluation trials, with an average yield level of 6 tonnes or more per hectare. The maize hybrids and composites recommended for cultivation are listed in Table 1 (Annexed).

2. Soils

Maize can be grown on a variety of soils ranging from sandy to clayey. But it performs best on well drained, aerated deep-loams and silt loams containing organic matter and nutrients. Highly saline, acidic, alkaline and water logged soils should be avoided for cultivation of maize crop.

3. Date of Sowing

The optimum date of sowing is important for winter maize so that the genotype grown can complete its life cycle under optimum environmental conditions. Generally, sowing should be completed before the end of October, preferably by mid-October. The temperature during second fortnight of October to mid November in most of the North India drop rather sharply, resulting in delayed germination and plant growth receives a major setback. Hence, any marked delay in sowing is likely to result in lower yield. Also, in late sown crops, there is an increased incidence of common rust, which is not a serious concern in timely sown crop. The extent of reduction in yield through delayed sowing however varies with the location. The most congenial sowing period for realizing high grain yield in different maize growing states given in Table 2.

Table 2: Recommended sowing time of *Rabi* maize in different states of India

States	Most suitable periods of sowing
Bihar	20 October- 15 November
Uttar Pradesh	20 October- 15 November
Andhra Pradesh	25 October- 20 November
Gujarat	15 October- 15 November
Maharashtra	20 October- 15 November
Tamil Nadu	20 October- 15 November
Madhya Pradesh	15 October- 15 November
Karnataka	15 October- 15 November
West Bengal & N E region	20 October- 10 November
Orissa	20 October- 10 November
Punjab	25 October- 15 November
Haryana	25 October- 15 November

In Punjab and Haryana, where the temperature at the time of sowing is low, it will be desirable to sow the crop on ridges. Sowing should be done on the southern side of the east-west ridge so that the optimum amount of sunshine is received and the seedbed remains warm.

4. Plant density and seed rate

A population of 90,000 plants/ha at harvest is desirable for realizing high grain yield in *Rabi*. A spacing of 60cm between rows and 18cm-20cm between plants would provide the desired plant population density. For this purpose, 20-22 kg of seed would be needed to sow one hectare of land. Before sowing, seed should be soaked overnight in warm (45°C at the time of seed soaking). This treatment helps in obtaining better plant stand and healthy crop. Seeds should be sown 4-5 cm deep.

5. Seed Treatment

Seed treatment with fungicide and insecticides is necessary to protect the maize crop from seed and soil borne diseases and insect- pests.

Table 3: Recommended seed treatment

Disease/insect-pest application	Fungicide/Pesticide	Rate of (g kg^{-1} seed)
Turcicum Leaf Blight, Banded Leaf and Sheath Blight, Maydis Leaf Blight	Bavistin + Captan in 1:1 ratio	2.0
BSMD	Aspran 35 SD	4.0
Pythium Stalk Rot	Captan	2.5
Termite and shoot fly	Imidachlorpid	4.0

6. Method of sowing

(i) Raised bed planting: It is the best method for maize during monsoon and winter season both under excess moisture as well as limited irrigation availability conditions. Sowing should be done on the southern side of the east/west ridges/beds , which helps in good germination. Planting, should be done at proper spacing. Preferably, the raised bed planter having inclined plate, cupping or roller type seed metering systems should be used for planting that facilitates in placement of seed and fertilizers at proper place in one operation that helps in getting good crop stand, higher productivity and resource use efficiency. Using raised bed planting technology, 20-30% irrigation water can be saved with higher productivity.

(ii) Zero-till planting: Maize can be successfully grown without any preparatory tillage under no-till situation with less cost of cultivation, higher profitability and better resource use efficiency (Picture 1). Under such condition one should ensure good soil moisture at sowing and seed and fertilizers should be

Picture 1. Zero- till planting

placed in band using zero-till seed-cum-fertilizer planter with furrow opener as per the soil texture and field condition. Large number of farmers particularly under rice-maize systems in Peninsular and Eastern India are practising successful zero till planting and getting higher profitability.

(iii) Transplanting: Maize can be successfully cultivated by transplanting seedlings especially in north-west and eastern plain regions of the country. This practice is particularly suitable after the harvest of late paddy, early harvest of crops like sugarcane or as a companion crop with autumn sugarcane. In multiple cropping system, transplanting of maize may be practical in north-west and eastern plain to avoid delay. This is also suitable for the Diara and Tal areas where flood water recedes late. For transplanting in second fortnight of January, the nursery should be sown from November 21 to 30 to obtain higher yields than the direct late sown crop. For transplating one hectare area, 25 kg seed is to be sown in nursery of 1/10 ha as well as 7.5 kg N, 2.5 kg P_20_5, 3.0 Kg K_2O and 1.0 kg Zinc sulphate may be applied to seed beds before sowing. Pre-emergence application of weedicide Atrazine @ 1.5 kg/ha is also recommended.

The seedling may be transplanted on southern slope of east west ridges or in flat fields. It should be removed by edge tools. The uprooted nursery plant should be kept under shade before transplanting but it should be completed at the earliest. In flat beds, seedling should be planted in furrow and their roots needs to be covered with soil manually. Transplanting on ridges gives relatively higher yield than in flat beds. First irrigation should be given immediately and second irrigation after 8-10 days of planting.

7. Nutrient management

There are several factors that affect the productivity of winter maize however, the fertilizer management is one of the most important factors that affect the growth and yield of maize. Maize is an exhaustive crop which requires all types of macro and micro nutrients in order to get better growth and exploit yield potential. Among the various nutrients, nitrogen is the principal nutrients which should be applied@ 150 kg N ha^{-1} in order to have better harvest. The efficiency of nitrogen utilization is better in *Rabi* than in *Kharif* season, primarily because of better water management and lower leaching losses. With better fertilizer response, it should be possible to substantially reduce the cost of production of every tonne of maize produced in *Rabi* season. The available quantity of farmyard manure should be applied before sowing, since a combination of organic and inorganic fertilizers give better results than the use of fertilizers alone.

A. **Dose of fertilizer:** The quantity of fertilizers to be applied depends mainly on soil fertility and the preceding field management. Therefore, for higher economic yield of maize, application of 10 t FYM ha^{-1}, 10-15 days prior to sowing supplemented with 150-180 kg N, 70-80 kg P_2O_5, 70-80 kg K_2O and 25 kg ZnSO4 ha^{-1} is recommended.

B. **Method of fertilizers application:** Full doses of P, K and Zn should be applied as basal preferably drilling of fertilizers in bands along the seed using seed-cum-fertilizer drills. Nitrogen should be applied in 5-splits as detailed below for higher productivity and use efficiency. N application at grain filling results in better grain filling. Therefore, nitrogen should be applied in five splits for higher N use efficiency (Table 4).

Table 4: Nitrogen application in five splits doses

S. No.	Crop Stage	Nitrogen rate (%)
1	Basal (at sowing)	20
2	V4 (four leaf stage)	25
3	V8 (eight leaf stage)	30
4	VT (tasseling stage)	20
5	GF (grain filling stage)	5

8. Weed control

Light hoeing is to be given as and when necessary for better control of weeds. Broad- leaved weeds and most of the grasses can be conveniently controlled with the application of Atrazine or Simazine @ 0.5-1.0kg a .i./ha in 1000 lit of water as pre-emergence spray. In zero-till maize production, pre-plant application (10-15 days prior to seeding) of non-selective herbicides viz., Glyphosate @ 1.0 kg a.i. ha^{-1} in 400-600 litre water or Paraquat @ 0.5 kg a.i. ha^{-1} in 600 litre water is recommended to control the weeds. Under heavy weed infestation, post-emergence application of Paraquat can also be done as protected spray using hoods.

9. Water management

The rainfall during *Rabi* is rather inadequate for successful cultivation of high-yielding maize hybrids. In fact, timely availability of assured irrigation is one of the major factors determining the success of crop. Where soils are generally light, it is desirable to schedule the irrigation 70% soil moisture availability throughout the period of crop growth and development. In heavy soils, a moisture level of 30% during the vegetative stage and 70% during the reproductive and grain –filling period is desirable for obtaining optimum yield.

Four to six irrigations are needed during the *Rabi* crop season. If six irrigations are given, they should be applied at the following at an interval of 20-25 days, one (essential) at the time of flowering, two after flowering and one at the early grain-filling stage. If only five irrigations are given, one irrigation at the vegetative stage may be avoided; and if only four irrigations are given, irrigation after the dough stage may be avoided. The irrigation should may, however be changed suitably if adequate rains are received.

10. Intercropping

Maize is a most versatile crop for growing inter crops, because of the wide row it needs,

Picture 2. Inter cropping Maize+Cabbage

Picture 3. Inter cropping Maize+Carrot

Picture 4. Inter cropping Maize+Potato

providing higher income to the farmers. Short-duration variation of pulses (pea, rajmash and other beans), most vegetables, and oilseed crop (soybean, linseed) can be successfully intercropped in maize (Picture 2, 3 & 4). The yield of pure maize under intercropping is in no way lower but the inter-crop is a bonus. It is also possible to intercrop wheat maize. Short-statured varieties of maize perform better under intercropping. The practice is particularly desirable under delayed sowing after late harvest of rice (Table 5).

Table 5: Recommended crops for intercropping with maize

Sl. No.	STATES	RECOMMENDED CROPS
1.	North-western Region (Punjab, Haryana, Delhi & Western U.P)	Pea, Rajmash, Lentil
2.	North-eastern Region (Bihar, Eastern U.P, Orissa, West Bengal & NE Region)	Pea, Rajmash, Potato, Lentil, Bakla & Onion
3.	Southern Region (Maharashtra, Andhra Pradesh, Karnataka & Tamil Nadu)	Fenugreek (Methi), Corriander, Sunflower & Cluster beans
4.	Central Region (Rajasthan, M.P & Gujarat)	Pea, Lentil, Onion, Garlic & Methi

11. Plant Protection

(i) Disease

Disease problem in *Rabi* is less as compared to *Kharif* maize. However, turcicum leaf blight and common rust occurs in moderate to high intensity. During *Rabi* season, post flowering stalk rots, particularly charcoal-rot occur predominantly in late sown crop, especially when temperature at maturity is high and the crop is subjected to soil-moisture stress. The best remedy to minimize yield loss due to these diseases is to grow resistant varieties/ hybrids.

Rust

There are two type of rust prevails i.e. Common rust (*Puccinia sorghii*) and Polysora rust (*Puccinia polysora)*

Common Rust (*Puccinia sorghii)*

Prevalent in subtropical, temperate and high land environment. Moderate temperature (16-25^{0}C) and high relative humidity favors the spread and development of disease. Disease appearance is common at the time of tasseling. Pustules are abundant on leaves, frequently occurring in bands as a result of infection that took place when the leaf tissue was in the whorl.

The circular to elongate, golden brown to cinnamon brown pustules are sparsely scattered over both leaf surfaces and become brownish black as the plant matures (Picture 5). Pustules are dark brown in early stages of infection, later the epidermis is ruptured and the lesion turn black as the plant matures.

Picture 5. Symptoms of Common Rust

Polysora Rust (*Puccinia polysora*)

Disease prevalent in Coastal areas of A.P. and Karnataka

Picture 6. Symptoms of Polysora Rust

The disease is favoured by mild temperature (27°C) and high relative humidity.The disease resembles common rust. The pustules appear on leaf are light cinnamon golden brown circular to oval (0.2-2.0 mm long) densely scattered on the upper surface of leaf (Picture 6). The uredinospores are yellowish to golden. Development of pustules on lower surface is more as compared to upper surface. The telia are circular to elongate, covered by epidermis and longer than those of common rust.Spray of mancozeb @ 2 - 2.5g/litre of water at first appearance of pustule.

Charcoal Rot (*Macrophomina phaseolina* (Goid) Tassi)

This disease is prevalent in comparatively drier maize growing areas. This disease also becomes apparent as the plant approach maturity. Affected plants dry prematurely, the affected internodes become disintegrated and show black discoloration. Presence of numerous, minute black sclerotia on the vascular bundles and inside the rind of the stalks is a distinguishing character (Picture 7 & 8). The disease is usually confined to first or second internode above soil level. Water stress at or after flowering has been found to predispose the plant to infection.

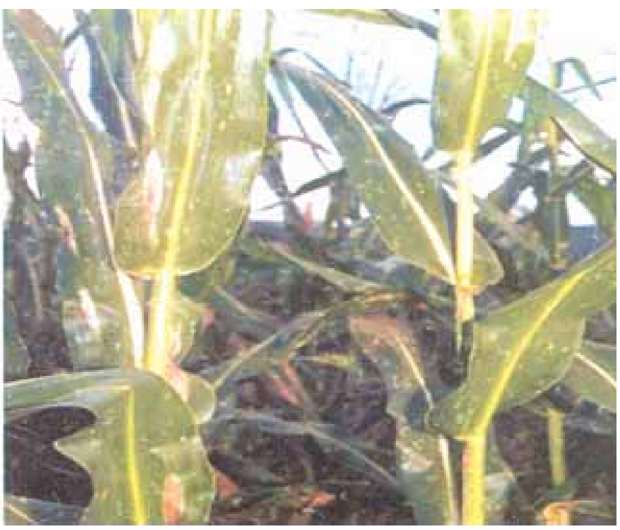
Picture 7. Symptoms of stalk rot

Picture 8. Stalk Rot affected field

Turcicum leaf blight (*Exserohilum turcicum*)

This is a fungal disease of maize prevalent in South India and seen both in *Kharif* and *Rabi* seasons.

The early symptoms of disease are oval, water-soaked spots on leaves and the later disease stage shows characteristic cigar shaped lesions that are 3 to 15cm long. These elliptical, long cigar-shaped gray-green or tan color lesions develop into distinct dark areas as they mature and become associated with fungal sporulation. Lesions typically first appear on lower leaves, spreading to upper leaves and ear sheaths as the crop matures (Picture 9 & 10). Under severe infection, lesions may coalesce, blighting the entire leaf. Yield losses as high as 70% are attributed to Turcicum leaf blight.To control, spray Zineb/ Meneb @2.5-4.0 g/ litre of water (2-4 applications) at 8-10 days interval.



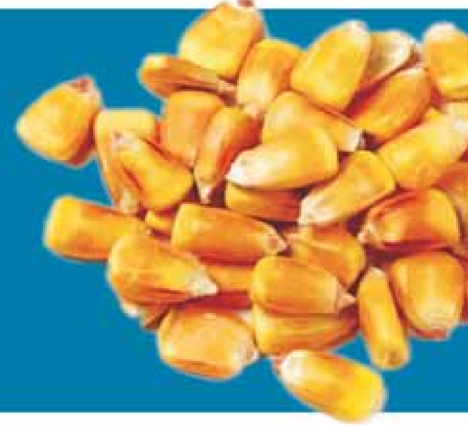
Picture 9. Symptoms of TLB

Picture 10. Symptoms of TLB

(ii) Insect Pests

Maize grown in *Rabi* is known to be free from the attack of major insect pests which usually attack *Kharif* crop. However, pink stem borer, ***Sesamia inferens*** is a major pest. The larvae attack almost all parts of the plant such as leaf, stem tassel, and ear. Due to larval feeding, the grown up plants show many slit-like oval elongated holes on the leaf blades.They also form tunnel inside the stem and exit holes at the surface.The decaying shoots in grown up plants cause cob to rot, thus causing complete loss of grain. To control this pest two sprays of Quinalphos 0.05% 15 days and 35 days after germination followed by second application with Trichlorphon 5G or Cabofuran 3G @ 0.5 kg a.i/ha 20 days after germination followed by second application 20 days after first recommendation.

A SUCCESS STORY

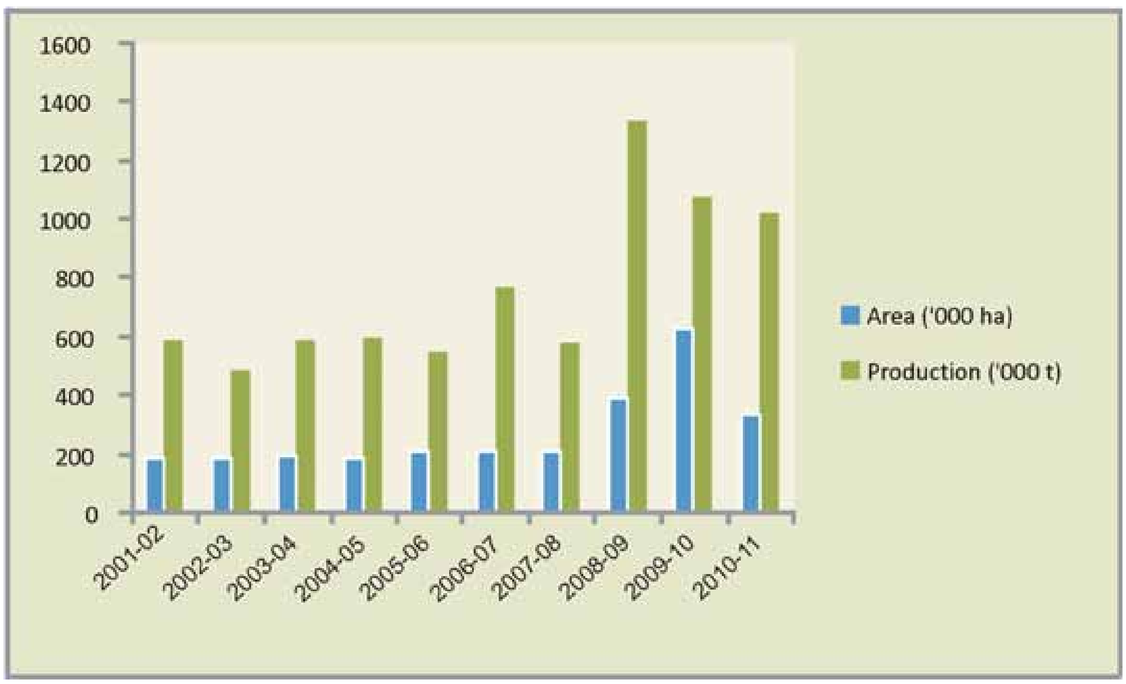


BIHAR

In Bihar, maize is cultivated over an area of around 0.65 million hctare and producing 1.43 million tons in major maize producing dristricts *viz.*, Khagaria, Madhepura, Begusarai, Saharsa and Katihar. Winter (*Rabi*) maize is cultivated mainly in Bihar with a production of 1.02 million tonnes, about 70% of the total production in the states (Figure 6). This gives unique position to the state in national maize market with most of maize processing units in north India depend highly on maize from the Bihar state for a significant period of time. With state productivity much higher than national productivity level, area under cultivation expected to rise as, the availability of good quality maize offers significant opportunities for entrepreneurs in the state. However, the level of processing in the state is presently quite insignificant. There is thus a large opportunity for maize processing units which can be set up for making a range of products.

Bihar's maize, which is primarily a *Rabi* crop, has been a success sector mainly due to the quality of the produce which has grown steadily in the last few years. Productivity of maize in Bihar is 2,541 kg/ha, which is far greater than the all-India average productivity of 1,907 kg/ha. Agricultural innovations such as winter maize have helped dispel the spectre of near-term starvation for many smallholders in Bihar.

The Ganges River runs straight across Bihar from west to east, creating a massive, level plain where most people live and practice agriculture. Rice and wheat are the staple crops of the region. Wheat dominates the cropping pattern during winter, or



Source : DACNET

Figure 6. Area & Production of Rabi Maize in Bihar, 2001 to 2011

Rabi season, the dry, cool period from October to April that counterbalances the monsoon when much rice is grown. Farmers also grow myriad other crops throughout the year, including pigeon pea, sorghum, pearl millet, pulses, peppers, and tobacco. Maize was traditionally a wet season crop, suffering from waterlogging, seasonal pests, and inadequate management.

In the early 1960s, national program researchers, with assistance from the Rockefeller Foundation, studied the suitability for Bihar of a range of maize hybrids and management practices, taking data on factors as planting density, sowing dates, fertilizer requirements, maturity class, storability, and pest control. The massive efforts include basic research to extension and seed production. As part of this, the researchers tested maize in the *Rabi* season. Yields were high and consistent, due among other things to the great number of sunny days and the long growing season, as well as the drier and cooler conditions, which were amenable to the crop but less so to pests. Farmers quickly began planting winter maize in Bihar, and the practice eventually spread to parts of Uttar Pradesh and Punjab. Although maize area can vary considerably from season to season, as farmers switch crops in response to shifting market conditions, *Rabi* maize is grown on about 0.4 million hectares in Bihar with high productivity as compared to *Kharif* season (Figure 7). Given its profitability (around US$ 250 per hectare, according to a 1986 study) and the availability of credit and inputs, most farmers practice fairly intensive management, seeding at high densities, irrigating and weeding the crop, and applying generous amounts of fertilizer.

With rich water resources and available irrigation in winter and summer seasons, irrigated area under maize increased and so have the yields. For the last two seasons, increased participation of national players and a few multinationals has led to a structural change in the maize ecosystem in Bihar.

Source : DACNET

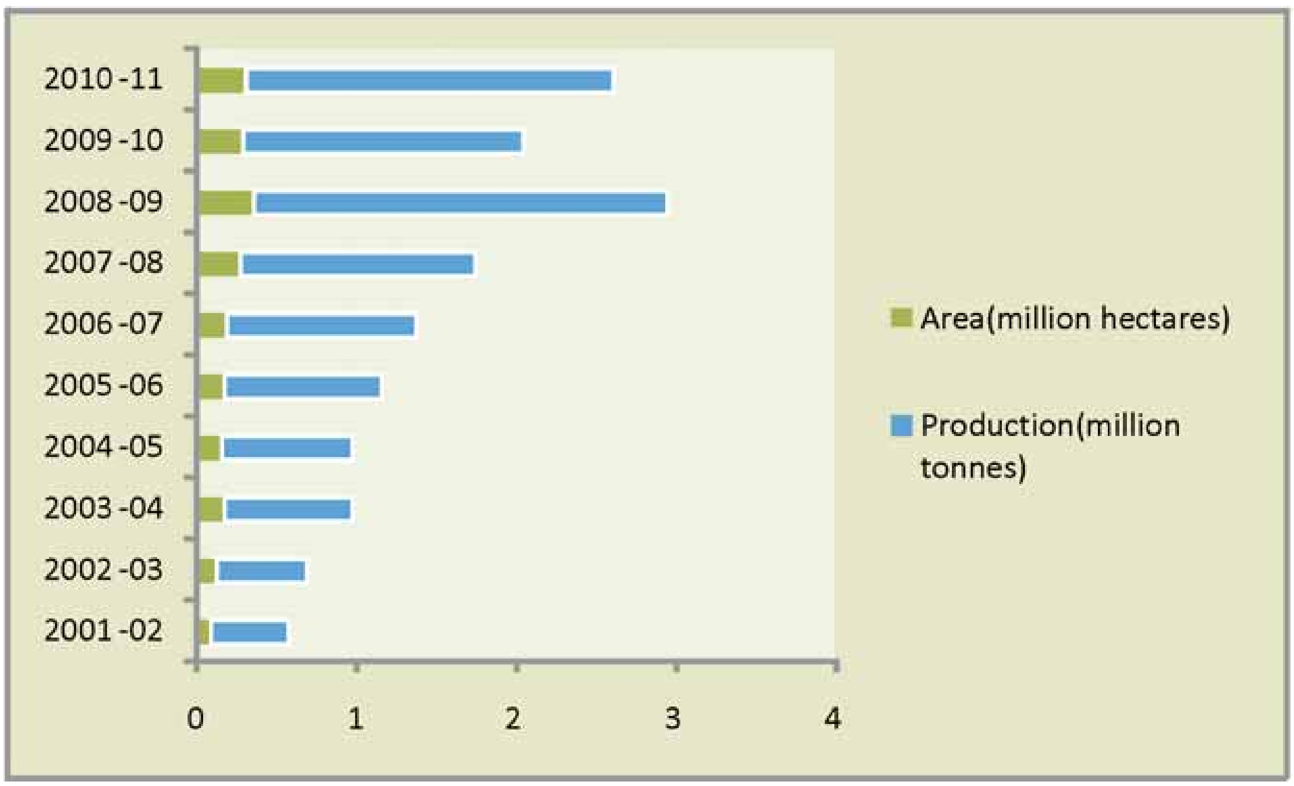
Figure 7. Comparison of productivity of maize in Kharif and Rabi seasons in Bihar

ANDHRA PRADESH

Andhra Pradesh is the non-traditional maize growing state but, the climate of the state is very favourable for the maize crop and hence maize can be grown in any season in the state. The trends in area, production and productivity of maize in *Rabi* season in Andhra Pradesh has shown a remarkable increase with the passing years (Figure 8). This shows that maize is occupying more acreage under non-traditional season as well as non-traditional areas that indicates that maize is emerging as one of the potential driver for crop diversification in the state. Moreover, winter maize is more assured crop with higher productivity potential compared to monsoon season (Figure 9). Therefore, areas where winter rice crop suffers due to water scarcity, the maize has emerged as potential alternative like, Guntur, Krishna , and west Godavari districts. This shift is due to no-till maize in rice-maize system and cultivation of Single Cross hybrids.

The Andhra Pradesh is a state of diverse soil and climatic conditions that lead to diversified farming systems. The major cropping system of the state is rice based rotations followed by sorghum, groundnut, cotton, sugarcane and maize systems. Maize systems are dominant in Telangana zones during monsoon season whereas during winter season, maize systems are mainly practised in Krishna and Godavari zones in rice fallows.

In coastal Peninsular India, rice-rice rotation is dominant system but during recent years double cropping of rice is becoming difficult due to shortage of irrigation water particularly during winters. Under such situations, possibility for alternate potential crops having economical competence and that can be taken under water scarcity situation having explored by the researchers and farmers. As an alternative, rice-pulses systems were tried by the farmer in the coastal district of Andhra Pradesh but due to lower productivity of

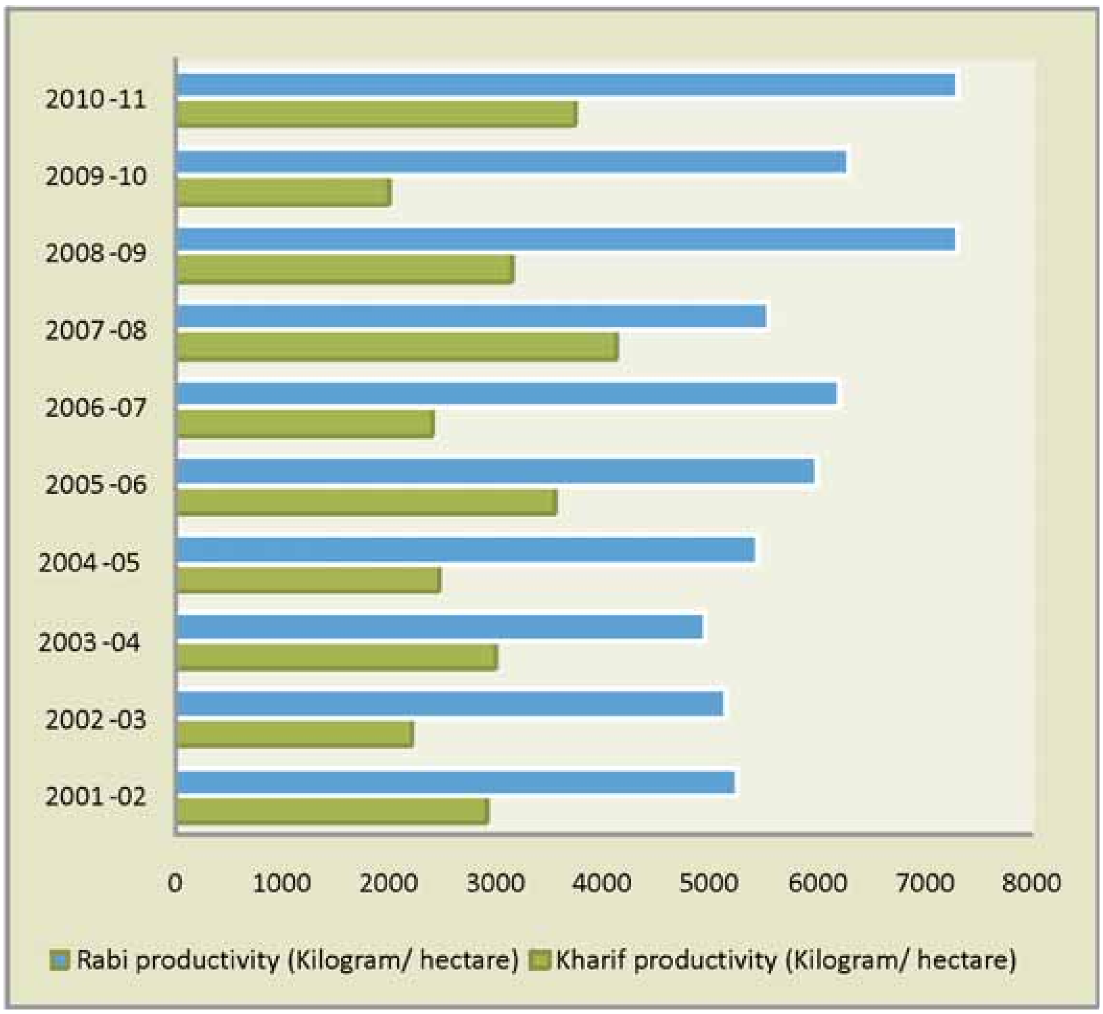


Source : DMR Technical Bulletin 2009/5, ML JAT *et.al*

Figure 8. Area & Production of Rabi Maize in Andhra Pradesh, 2001 to 2011

pulses could not sustain. Therefore possibility of maize in this non traditional maize growing region was explored that has shown promise. Due to higher productivity and profitability and assured alternative winter crop after rice, the acreage of maize in coastal Andhra Pradesh has shown an increasing trend and the rice-maize has emerged as a potential cropping system in coastal region of Andhra Pradesh concentrated in Guntur, Krishna, West and east Godavari and few pockets of Telangana.

Under the emerging and potential crop sequence (rice-maize) in coastal region of Andhra Pradesh, the conventional tillage for planting maize under heavy textured soil of rice ecologies needs 25-30% higher energy for field preparation that not only limits the farm profitability but also delays of planting of maize which in turn leads to lower productivity. Generally rice is harvested during second fortnight of November in case of zero tillage under rice-maize rotation the farmers can plant maize in time but if maize is planted after repeated conventional tillage, the planting gets delayed for ploughing and farmers have to wait for optimum soil moisture. Further the no till maize in rice fallow demonstrated a potential benefit of saving on cost of production changing from Rs 3800-5500 ha^{-1}



Source : DACNET

Figure 9. Comparison of productivity of maize in Kharif and Rabi seasons in Andhra Pradesh

NEW IDEAS, NEW ADVANCES

OPPORTUNITIES AND CHALLENGES

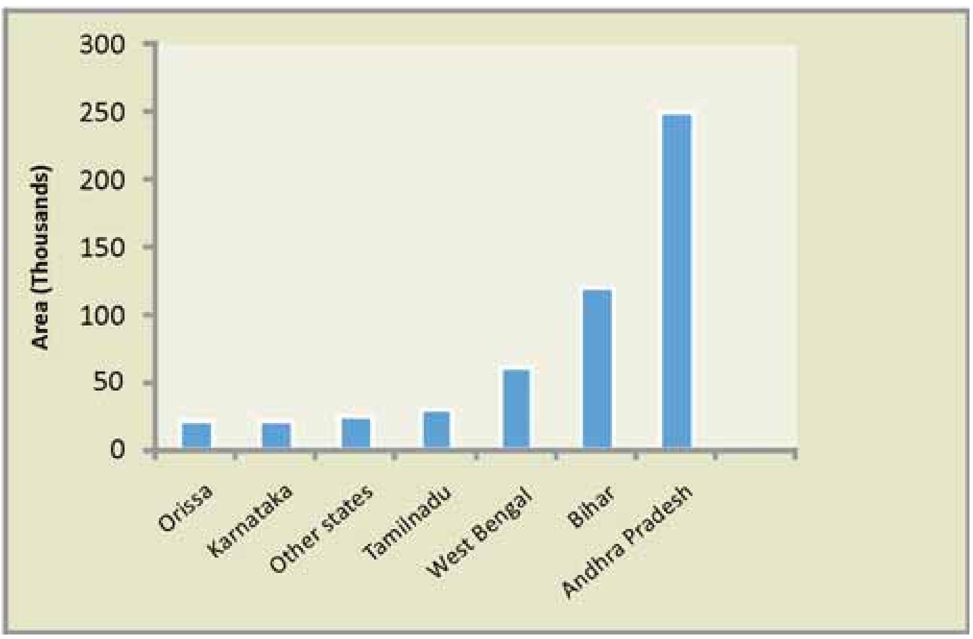
Maize (Zea *mays* L.) is traditionally a monsoon crop (June-October) in India, but is extensively cultivated in large parts of eastern and southern India in winter (October-April) season .To increase the trend of Rabi maize, **opportunities** to be searched and strategies to be made to meet the **challenges.**

Area expansion

Cultivation during winter season spreads in entire plain region of the country where temperature during the growth periods does not go below 10^0 C. The sensitivity of a crop species to low temperature and chilling frequently restricts the environment in which it can be cultivated. Hence, *Rabi* maize cultivation is possible in Eastern Uttar Pradesh, Bihar, Odisha, Tamil Nadu, Karnataka, Andhra Pradesh, Gujarat, Madhya Pradesh, South and east Rajasthan, lower elevations of Sikkim, West Bengal, Punjab and Haryana. Rabi maize can be taken in lower foothills which usually do not re+ceive frost.

Diversification of agro ecosystems

Under the changing climate scenario maize being a photo-insensitive crop has better options for adaptation and mitigation of these climatic changes. The limitation of rising temperature during grain filling of wheat particularly in eastern India, and declining yield of boro rice in West Bengal and Orissa and water scarce areas in Peninsular India (AP and Tamil Nadu) affecting yield of *Rabi* rice has shown a path to maize as better option. (Figure 10). Peninsular India is considered to be a neutral environment for maize wherein maize can be cultivated in either of the seasons. Therefore, it is emerging as a potential driving



Source : Timsina *et.al,* 2010

Figure 10. Area under R-M system in India

force for diversification i.e. diversification of rice-rice with rice-maize and other maize based high value cropping systems in water scarcity/lowering of water table is a major concern in rice growing belt of India and making rice cultivation non-remunerative. Hence, maize has emerged as a potential as well as profitable crop in these areas. The *Rabi* rice in Peninsular India and upland rice in Odisha and NEH region has low productivity. Therefore maize is the only suitable alternative crop and more area is likely to shift towards maize cultivation in near future in these non-traditional areas. Wheat crop adversely affected with terminal heat due to sudden rise in temperature during crop growth and maturity but this favours maize crop positively.

Rice-rice is common in tropical climate with distinct dry and wet seasons such as in South India, and in sub-tropical areas with mild cool winter climate such as in Bangladesh, Eastern India, and Eastern Nepal. Rice-wheat systems is extensive in the sub-tropical areas of the Indo-Gangetic Plains (IGP) while R-M systems exist in all climates ranging from tropical to sub tropical to warm temperates (Table 3). Rice-maize systems, however, are less extensive as compared to R-W or R-R if total area under these cereal systems is considered. The productivity level of winter maize is higher as compared to *Kharif* sown maize because of comparatively favourable environmental conditions in peninsular India. Rice-maize systems are practiced mostly in the south (Andhra Pradesh, Tamil Nadu, and Karnataka) and in the northeast (Bihar and West Bengal) parts of India with acreage of more than 0.5 Mha

Table 3 Key emerging R-M agro-ecosystem in South Asia

Key features	Current systems	Emerging systems	Key examples
A. Tropical, warm, semiarid. no winter Tropical monsoon with longer dry season; both, rice and maize not limited by low temperatures and can be grown all year round	Rice-rice Rice-rice-pulses	Rice-maize	Cauvery Delta (Tamil Nadu), Kamataka and A.P., India
B. Sub-tropical, subhumid. warm summer mild cool winter Subtropical monsoon with cool winter and summer rainfall; rice but not maize maybe limited by low temperatures	Rice-wheat Rice-*Boro* rice	Rice-maize Rice-rice maize Rice-potato-maize	Central, western, and N\W Bangladesh; Eastern Terai, Nepal; West Bengal, Eastern UP and Bihar. India
C. Sub-tropical to warm temperate, subhumid, semiarid, warm summer, mild to severe cold winter			
i. Sub-tropical monsoon with cold winter and summer rainfall; both rice and maize limited by low temperatures and can't be grown for some time in winter	Rice-wheat	Rice-maize	North and NW India, Central and western Tcrai and mid-hills, Nepal
ii. Sub-tropical to warm temperate, semiarid. with hot summer and cool to cold winter; very low rainfall; both riee and maize limited by low temperatures and can't be grown for some time in winter	Rice-wheat Cotton-wheat Sorghum-wheat	Rice-maize Rice potato-maize	Punjab and Sindh, Pakistan

(Source: Timsina *et al.* 2010)

Maize is considered to be a better alternative to wheat or *Boro* or *Rabi* rice due to several reasons: (a) wheat encounters several biotic stresses, and most importantly, abiotic stresses due to terminal heat stress in the IGP, wheat is often vulnerable to temperature fluctuation resulting in shrivelled grains and poor yield, (b) evidences of declining yield of *Boro* rice in West Bengal and Orissa, and (c) water scarcity in Peninsular India affecting yield of *Rabi* rice in Andhra Pradesh and Tamil Nadu. Peninsular India is considered to be neutral environments where maize can be cultivated in all seasons and this is emerging as a pot .In particular, maize has fewer pest and disease problems than *Boro* rice and wheat.

There is a vast opportunity for intensification of winter maize in flood prone areas as to compensate for the loss during *Kharif* season with proper planning for seeds, inputs and improved management practices and crop diversification. The medium and uplands where subsistence yield of wheat, *Rabi* rice and other winter crops is obtained, could be substituted by winter maize in Bihar, West Bengal, Eastern UP, Orissa, parts of Jharkhand etc. In general, any late maturing single cross-bred variety of *Kharif* season is equally good for winter season. Winter maize (170-180 days duration) has the clear cut comparative advantages of low incidence of diseases and insect pests, is not affected by temperature rise during winter (as the wheat is) and do not suffer on account of heavy rainfall.

Breeding opportunities

To increase Rabi maize production, it has to be promoted in non-traditional areas and to be expanded in traditional zones. Current trend of growing maize in non-traditional areas during winter seasons has increased the likelihood that a maize plant will spend most part of early development under suboptimal temperature conditions. In Indo-Gangetic Plains region the winter season maize crop invariably face severe low temperature during winter months. The average minimum temperature may fall below 5°C or even less, especially in the North-West Plains of Indo-Gangetic Plains. Adaptation of maize to winter season requires genetic improvement for

Picture 11. Purpling of leaves

cold tolerance, which implies vigorous seedling growth without suffering with cold injuries under low temperature conditions.

The extreme cool temperature affects the maize growth in a number of ways right from emergence till flowering and seed-setting. Low temperature at planting greatly affects germination. Prolonged exposure to low temperature during the vegetative phase results in reduction in plant height, yellowing of the leaf, chlorosis and tip firing due to the death of leaf tissues (Picture 11, 12, 13 & 14). Cold stress occurring at reproductive stage severely affects flowering and results in reduced tassel size/ branches, delayed anthesis, pollen grain death, reduced silk size, and in certain cases no seed -setting, thereby, considerably affecting the yield.

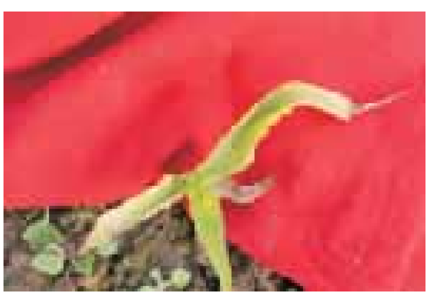
Picture 12. Leaf chlorosis due to low temperature

Being cold sensitive plant maize is prone to physiological damages also during non-freezing suboptimal temperatures. Leaves of maize, which develop under low temperature conditions, are characterized by a lower photosynthetic capacity, lower quantum efficiency of CO_2-fixation, and lower quantum efficiency of electron transfer at PSII (/PSII) than leaves which develop under more favorable conditions. One reason for the lower photosynthetic performance might be the perturbation of chloroplast development, specifically, the limited ability of maize leaves to develop a functional photosynthetic apparatus at low temperature.

Picture 13. Chlorotic bands on leaves

Tropical maize is highly sensitive to cold stress during vegetative growth stage. However, there is considerable genotypic variability available for various traits, such as - photosynthetic pigments, growth and development traits.

Selection of genotypes using secondary traits, such as- leaf appearance and extension rate, visual score for cold injuries, reduced electrolyte leakage along with grain yield under cold stress may be used as a selection index for identification and further improvement of cold tolerance in tropical maize. Presence of genetic variation for these secondary traits indicates that alleles are available in breeding materials that can improve cold tolerance. Considering the above facts, the most viable strategy to combat low temperature stress is to identify the plant traits affected under cold to develop effective selection criteria for identification of cold tolerant genotypes.



Picture 14. Leaf-tip drying

New Production Technologies

(i) Soil management: Even without climate change, deteriorating soils are one of the main challenges. Reducing vulnerability of crop, it demands a turn-around in soil management. Soil organic matter is a critical factor. Increasing organic matter content improves soil fertility, nutrient supply, soli structure, water-holding capacity, and a host of other vital soil functions. To improve soils, conservation agriculture is emerging as a big boost for maize production. Conservation agriculture is based on minimal soil disturbance (reduced or no tillage), combined with organic matter retention and diverse crop rotations. As well as reducing erosion and improving soil structure and soil-water dynamics, this approach also saves on labour, time, fuel and machinery wear. A good example of the effectiveness of conservation agriculture is the rapid spread of **'ZERO TILLAGE'** technology in Andhra Pradesh's rice-maize system.

(ii) Water management: Water is crucial input for augmenting agricultural production towards sustainability in agriculture. Scientific water management aims to provide suitable soil-moisture environment to the crop to obtain optimum yield commensurate with maximum economy in irrigation water and maintenance of soil productivity. During the winter season less water is required at early stage of crop while, at later crop growth stages water requirement increases due to rapid increase in evapo-transpiration demand. Amongst the various irrigation scheduling approaches, climatological approach has been found to be better, since it integrates all the weather parameters giving them their natural weightage in a given climate-water-plant continuum. A more practicable and understandable approach based on the ratio of fixed amount of irrigation water (IW) to cumulative pan evaporation (CPE) is much desired. Moreover, a close relationship exists between the rate of consumptive use of crop and the rate of evaporation. A very scanty work has been done on irrigation water requirement of winter maize in relation to nitrogen dose and plant density.

(iii) *Optimum date of sowing*: The time of sowing is a non monetary input, which plays significant role in production and productivity of any crop, important for winter maize so that the genotype grown can complete its life cycle under optimum environmental conditions.

(iv) *Optimum plant density*: It provides conditions for maximum light interception right from early periods of crop growth. Although, winter maize responds better even upto 90,000 to 1,00,000 plants ha^{-1}, the recommended plant population during winter in Northern Karnataka is only 55556 plants ha^{-1} as that of monsoon crop. Moreover, only few studies have been conducted to evaluate the response of *Rabi* maize to plant density under irrigated conditions

(v) *Nutrient management:* There are several factors that affect the productivity of winter maize however, the fertilizer management is one of the most important factors that affect the growth and yield of maize. Maize is an exhaustive crop requires all types of macro and micro nutrients for better growth and yield potential. Among the various nutrients, nitrogen is the principal nutrients for better harvest require approximately 150 N_20 kg ha^{-1}. However, high yielding R-M systems can also accelerate the problem of secondary and micronutrient deficiencies, not only because larger amounts are removed, but also because the application of high rates of N, P, and K to achieve yield targets often stimulates the deficiency of secondary and micronutrients. Proper nutrient management of exhaustive systems like R-M should aim to supply fertilisers adequate for the demand of the component crops, and apply those in ways that minimise loss and maximise the efficiency of use. Of all the nutrients, N, P, and K remain the major ones for increased and sustained productivity.

NO-TILL PROTECTING OUR SOIL

No-till
REDUCES SOIL EROSION

No-Till
SAVES BILLIONS
of money in water treatment and waterway maintenance

No-Till
CONSERVES MILLION
gallons of fuel per year

"The last two decades saw the revolution in rice and wheat, the next few decades will be known as maize era".

- Noble Laureate Dr. Norman E. Borlaug
Father of Green Revolution

CONCLUSION

In view of the changing farming scenario in the country, maize has been emerging as one of the potential crop that addresses several issues like food and nutritional security, climate change , water scarcity, farming systems and bio-fuels. *Rabi* maize cropping can provide insights on intensive agriculture and other strategies for meeting future food production challenges and will be one of the important cereals in food security of the country.

We are at a crossroads in the development of our country's food security. Food security is one of the basic human rights that is in jeopardy.

Building on several years of research by DMR and AICRPM centres and private partners, we know how to make agricultural and other natural resource-based systems more productive and more sustainable. Food security adds urgency to the situation, but it also provides an opportunity. To do this, we need new ways of working, new non-traditional partnerships and truly integrated approaches. The transformative research programme provides a framework for this, by doing so, to go beyond their traditional boundaries and open up new and unique possibilities in the search for solutions.

Table 1. List of Hybrids (H) and Composites (C) varieties of late maturity groups for different states for rabi season

STATES	Late maturity
Delhi	**H:** PMH 3, Buland, NK 61, Pro 311, Bio 9681, Seed Tech 2324,HM11,HM8
Punjab	**H:** PMH 3, PMH-1 , Buland, Sheetal , Pro 311, Bio 9681, NK 61, Pro 311, Bio 9681, Seed Tech 2324,HM11,HM8
Haryana	**H:** PMH 3, Buland, ,HM 5, NK 61, Pro 311, Bio 9681, Seed Tech 2324,HM11,HM2,HM1,HM8
Uttar Pradesh	**H:** PMH 3, Buland, Pro Agro 4212, Pro 311, Bio 9681, NK 61,Seed Tech 2324,HM8
Rajasthan	**H:** Pro 311, Bio 9681, Seed Tech 2324, HM8
M.P.	**H:** Pro 311, Bio 9681, Seed Tech 2324
Gujarat	**H**: Pro 311, Bio 9681, Seed Tech 2324 **C:** G M 3, Ganga safed 2
Andhra Pradesh	**H:** The late maturing hybrids of Kharif e.g. Kargil 900 M, Seed Tech 2324, Pro 311, Bio 9681, Pioneer 30 v 92, Prabal, 30 V 92, 900 M
Tamil Nadu	**H:** COHM 5, Prabal , Pro 311, Bio 9681, Seed Tech 2324, 30 V 92, 900 M
Maharashtra	**H:** Prabal, Pro 311, Bio 9681, Seed Tech 2324, 30 V 92, 900 M
Karnataka	H: Nithya Shree, DMH 1, DMH 2, 900 M, Bio 9681, Prabal, Pro 311, Bio 9681, Seed Tech 2324 **C:** NAC 6004, 30 V 92
Bihar	**H:** Rajendra Hybrid 2, Rajendra Hybrid 1, Pro 311, Bio 9681, Seed Tech 2324, 30 V 92, 900 M **C:** Hemant, Suwan & Lakshmi
Jharkhand	**H:** Pro 311, Bio 9681, Seed Tech 2324 **C:** Suwan
Odisha	**H:** Pro 311, Bio 9681, Seed Tech 2324 , PAC 705
West Bengal	**H:** Pro 311, Bio 9681, Seed Tech 2324
Himachal Pradesh	**H:** Pro 311, Bio 9681, Seed Tech 2324
NEH Region	**H:** Pro 311, Bio 9681, Seed Tech 2324 **C:** NLD white
Chhattisgarh	**H:** PEHM 1, Pioneer 30 V 92 & 30 R 26, Bio 9681, Pro 4640 & 4643, 900 M
Assam	**C:** NLD white,

* H: Hybrids; *C: Composites

ONE KERNEL, MANY USES

Acetic and amino acids
Alcoholic beverages and brewing
Antibiotics
Aspirin
Baby food
Bacon
Baked goods
Bakery products
Baking powder
Batteries
Blankets and bedding
Bookbinding
Breadings, coatings and batters
Cake, cookie, dessert mixes
Candies
Canned fruits, fruit fllings
Caramel color
Carbonated and fruit beverages
Cardboard
Carpet tile
Cereals
Chalk
Charcoal briquettes
Cheese spreads
Chewing gum
Citric acid
Cleaners, detergents
Coatings on paper, wood and metal
Coffee whitener
Color carrier for printing
Condiments
Confections, chocolate
Corn bread
Corn chips
Corn fakes
Cornmeal mixes
Cosmetics
Crayons
Disposable diapers
Doughnuts
Dried soups
Drink cups, plates and cutlery
Dusting for pizzas
Dyes and inks
Electroplating and galvanizing
English muffns
Enzymes
Fermentation processes
Fireworks
Food acids
Food coloring
Food packaging
Fritters
Frosting and icing
Frozen and dried eggs
Frozen pudding
Glues and adhesives
Gravy mixes
Hams
Hot dogs, bologna
Hush puppies
Ice cream and sherbets
Industrial chemicals
Industrial flters and water
Industrial sweetener
Insecticides
Instant breakfast foods
Instant pudding mix
Instant tea
Jams, jellies, preserves
Laminated building materials
Leather tanning
Lubricants
Mannitol
Marshmallows
Matches
Meat products
Metal plating
Muffns
Ore and oil refning
Organic solvents
Paints
Pancake mixes
Paper, recycled paper
Peanut butter
Pet food
Pharmaceuticals
Pickles and relishes
Plastics
Potato chips
Powdered mixes
Powdered sugar
Precooked frozen foods
Rayon
Rubber tires
Salad dressings
Salt
Sausage
Seasoning mixes
Shampoo
Shaving cream
Shoe polish
Snack foods
Soaps and cleaners
Soups
Spices
Spoon bread
Sports and active wear
Spray cooking oil
Surgical dressings
Textiles
Theatrical makeup
Tomato sauces
Vinegar
Wallboard and wallpaper
Wine
Worcestershire sauce

NOTES

भा.कृ.अनु.प.
ICAR

Directorate of Maize Research

(Indian Council of Agricultural Research)
Pusa Campus, New Delhi 110012 (India)
Website : www.maizeindia.org
Email: pdmaize@gmail.com
Phone: 011-25841805, 25842372, 25849725
Fax: 011-25848195