Chapter

# Improved Technologies for Higher Maize Production

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## Abstract

An array of production technologies, from land preparation to harvesting, has been recommended for maize crop. Being non-tillering crop, optimum plant population can be achieved if suitable crop establishment techniques like method of sowing, sowing time, seed rate, seed treatment, crop geometry etc., are followed. Weeds can be managed well either by two hoeings 15–30 days after sowing or herbicides like atratаf 50 WP (atrazine) at 2 kg/ha on medium to heavy textured soils and 1.25 kg/ha in light soils within 10 days of sowing, using 500 litres as pre-emergence or spray 262.5 ml/acre laudis 420 SC (tembotrione) in 375 litres of water at 20 days after sowing. Integrated nutrient management strategy renders use of farm yard manure at 10–15 t/ha, Paddy straw compost at 450 kg/ha or synthetic fertilizers at 120 kg N, 60 kg $P_2O_5$ and 40 kg $K_2O$ per hectare for hybrids and 80 kg N, 30 kg $P_2O_5$ and 20 kg $K_2O$ per hectare for composites. Integrated pest management approach emphasizes on use of physical, chemical or biological measures for the control of insect-pests. Maize borer can be controlled by spraying coragen 18.5 SC at 75 ml using 150 litres water/ha. Drying of maize produce can be done sun drying, smoking or air drying for fetching better market price.

**Keywords:** maize, production technologies, crop establishment, integrated nutrient management, integrated pest management, maize drying

## 1. Introduction

Maize is known as the Queen of Cereals' due to its' demand and wider adaptability. It is the second most important cereal crop in the world in terms of acreage and production. Global production of Maize was about 1040 million MT in the year 2016–2017, where in USA and China contributed about 38 and 23%, respectively. In India, maize is the 3rd most important food crop after rice and wheat, where about 15 million farmers are engaged in maize cultivation [1]. In India, Andhra Pradesh ranks first in maize production followed by Karnataka with per cent share of 20.9 and 16.5, respectively [2]. It has a share of 9% in about Rs. 100 billion agriculture sector gross domestic product [3]. Maize can be cultivated successfully in loamy sand to heavy clay, well aerated, neutral pH soils. As of tropical origin, it is highly sensitive to water stagnation, so avoid the cultivation in low-lying or poor drainage fields. Furthermore, extended low temperature less 5°C severally affects the crop. Optimum range of temperature for better crop growth and yield realization is 25–35°C [4]. Being day neutral, maize crop can be cultivated throughout the year which leads to high yield levels in a short period of time. In this chapter, we

are going to discuss an array of different production technologies to be followed by farmers for successful cultivation and better realization of yields. A brief outline of the chapter is given below.

## 2. Origin and distribution

Central America and Mexico is the primary centre of origin of maize which consists of a diversity of maize crop. Various studies reveal that maize crop was a significant crop in Mexico about 5000 years ago. USA has the largest area under maize crop followed by Brazil, China, Mexico and India. USA also stands first in terms of production followed by China. In India, Uttar Pradesh, Bihar, Rajasthan, Madhya Pradesh and Punjab are the major maize growing states. Highest acreage and production is in Uttar Pradesh while average yield/ha is recorded in Andhra Pradesh [2, 5].

## 3. Climatic requirements

Maize crop can grow under diverse conditions from sea level to about 3000 m altitude throughout the year in many parts of the country. In Northern India, *kharif* (monsoon) season is main growing period while in Southern India it can be grown from April to October as warm weather conditions prevail for longer period. Maize crop requires 21 and 32°C temperature for proper germination and growth with considerable moisture availability. For instance, 50–75 cm of well distributed rain is conducive for proper growth. During flowering, high temperature and low humidity damages the foliage, desiccates the pollens interferes with pollination and decreased grain formation. Maize is highly sensitive to water stagnation especially during early period of growth [2, 5].

## 4. Improved production technologies

### 4.1 Crop establishment

*4.1.1 Selection of cultivar*

Type of cultivar/hybrid to be grown depends on the crop season namely, spring, *Kharif* or *Rabi*. Cultivars can be proffered based on length of growing season, availability of optimum moisture regime. Depending upon above factors, cultivars can be selected as follows (**Table 1**) [6]:

*4.1.2 Sowing time*

Due to occurrence of diverse climatic conditions in country, planting time varies from place to place. Optimum planting time in different agro-climatic regions is described in **Table 2** [2]. The optimum time to sow the crop depends on availability of irrigation facilities. For example, if irrigation facilities are available, maize crop can be sown about 2 weeks before onset of monsoon while under rainfed conditions, crop is sown with the onset of monsoon to have optimum moisture regime so that proper plant stand can be maintained in field. In Punjab, Maize crop can be sown during all seasons at following sowing times (**Table 3**) [7, 8]:

| Length of cropping season (days) | Type of cultivar |
|---|---|
| More than 100 | Late maturing |
| 90 to 100 | Medium maturing |
| 80 to 90 | Early maturing |

**Table 1.**
*Choice of cultivar as per length of growing season.*

| Agro-climatic region | Optimum planting time |
|---|---|
| Indo-gangatic plains | 15 June–15 July |
| North-western hills | April-early May |
| North-eastern hills | First fortnight of March |
| Peninsular region | May–June |

**Table 2.**
*Optimum planting of maize in different agro-climatic regions.*

| Season | Planting time |
|---|---|
| *Kharif* | Last week of May to last week of June |
| Spring | 20th of Jan to 15th of Feb |

**Table 3.**
*Season wise planting time maize.*

| | |
|---|---|
| Hybrids | 20–25 kg/ha |
| Composites | 18–20 kg/ha |

**Table 4.**
*Seed rate of maize hybrids and composites.*

### *4.1.3 Seed rate*

Being a non-tillering crop it cannot compensate for the lost space if proper plant stand is not maintained under field conditions. So maintenance of 60–65,000 plants/ha is pre-requisite for realizing maximum yield. Sowing of the crop should be done 60 × 20–25 cm crop geometry. For hybrids and composites, seed rate can be used with respect to seed weight and requirement of plant population as given in **Table 4** [2, 8].

### *4.1.4 Seed treatment*

Seed treatment plays a pivotal role in prevention of diseases and availability of nutrients to growing crop. For instance, seed treatment of maize with Bavistin or Derosal or Agrozim 50 WP (Carbendazim) @ 3 g/kg seed prevents the attack of seed and soil borne diseases in maize crop. Furthermore, treatment of seed with consortium (biofertilizer) @ 1.25 kg/ha helps in yield enhancement and improvement of soil health [2, 7, 8].

| Purpose | Crop geometry |
|---|---|
| Grain crop | 60 cm × 20 cm; 75 cm × 20 cm |
| Baby corn | 30 cm × 20 cm; 60 cm × 15 cm |
| Fodder | 30 cm × 10 cm |

**Table 5.**
*Crop geometry of maize to be followed as per requirement.*

### *4.1.5 Crop geometry*

Crop geometry has direct effect on inter and intra-plant competition in field crops. Maize crop can be planted in varied crop geometries (**Table 5**) depending upon the purpose of cultivation [2, 8]. Interculture operations like thinning, gap filling and earthing-up play critical role in performance of maize crop. Thinning needs to be performed about 10 days after germination to keep 1 plant/hill. Further, 2 earthing-ups are required in maize crop. First at 35–40 and 2nd at 60–65 days after germination [9].

### *4.1.6 Method of planting*

Although crop establishment is a series of events that depends on interactions of seed, soil moisture, method of sowing, machinery etc. but method of planting plays an important role in establishment of crop under given set of conditions. Maize is mainly sown directly through seed by using different methods of tillage & establishment. Recently, resource conservation technologies (RCTs) namely, zero tillage, minimum tillage, surface seeding etc. had came in practice in various maize based cropping system and are cost effective and environment friendly. Following are major planting methods that vary from situation to situation.

### *4.1.7 Zero tillage*

Maize crop can be cultivated without any primary tillage under no-till (**Figure 1**) with decreased cost of cultivation and better resource use efficiency. In this situation, maintenance of proper soil moisture at sowing and band placement of seed and fertilizers with zero-till seed-cum-fertilizer planter with furrow opener as per the soil texture and field conditions is pre-requisite. The technology is followed by large number of farmers especially under rice-maize and maize-wheat systems in peninssular and eastern India. If the field is infested with weeds, farmers can go for foliar spray of gramoxone 24 SL (paraquat) @ 1250 ml/ha about 24 hours before planting of maize crop [2, 7, 8].

### *4.1.8 Ridge/raised bed planting*

This planting method (**Figure 2**) is considered best for cultivation during monsoon and winter seasons both under excess and limited water availability conditions. On non-uniform lands, this method is most suitable for successful cultivation of maize crop. Planting of crop needs to be done on the southern side of the east–west ridges/beds for better exposure to sunlight during winters and better crop stand. Raised bed planter having inclined plate, cupping or roller type seed dropping system should be used for planting that facilitates proper placement of seed and fertilizers in single operation for having good crop stand, higher productivity and resource use efficiency. Irrigation water can be saved to the tune of

**Figure 1.**
*Maize crop sown under zero tillage system.*

**Figure 2.**
*Planting of maize crop on the ridges.*

**Figure 3.**
*Flat sowing of maize crop.*

20–30%. Under temporary excess soil moisture/water logging due to heavy rains, the furrows will act as drainage channels and crop can be saved from excess soil moisture stress [2, 5, 7, 8].

*4.1.9 Flat sowing*

Maize crop can be cultivated by conventional tillage flat planting (**Figure 3**) depending upon soil type and availability of irrigation facilities. Light soils have high

**Figure 4.**
*Maize crop establishment through transplanting system.*

infiltration rate and low water holding capacity, so farmers can go for flat planting of maize crop. Under rainfed conditions, to have better moisture availability to crop for longer period, flat planting becomes better alternate. Flat planting is also beneficial when no tillage system gets infested with high weed population and chemical/manual weed control becomes non-economical [7, 8].

*4.1.10 Transplanting*

It is better establishment technique winter maize (**Figure 4**) in the intensive cropping system where field cannot be vacated on time, to prevent the delayed planting and crop loss due to low temperature. Under this situation, nursery of the crop is raised on a smaller portion of land and seedlings are transplanted in required field as and when they achieve certain age. For example, if the fields are to be vacated during December–January, it is advisable to go for nursery sowing 30–40 days before the transplanting. Seedlings can be transplanted in the furrows followed by light irrigation [2, 5].

*4.1.11 Furrow planting*

Furrow planting (**Figure 5**) of maize is recommended when crop is to be cultivated during spring season as high evaporative losses may lead to water deficit stress in flat and raised bed or ridge sowing [2, 5, 7, 8].

**4.2 Water management**

Water requirement of the maize crop varies from 400 to 600 mm [10]. Excess or shortage of moisture can have harmful impact on the crop growth. Proper drainage of standing water and meeting the crop needs at critical stages play a pivotal role in better crop performance. Especially for winter maize, it is advisable to keep soil wet (frequent & mild irrigation) during 15 December to 15 February to protect the crop from frost injury [3].

*4.2.1 Flood irrigation*

Flood method of irrigation is followed where maize crop is cultivated with flat sowing. Crop is irrigated as and when required. Generally, young seedlings, knee high stage (V8), flowering (VT) and grain 7.

**Figure 5.**
*Crop establishment by furrow planting.*

filling (GF) are critical stages and hence irrigation should be ensured at these stages [2, 7, 8].

*4.2.2 Furrow irrigation*

When crop is cultivated as ridge/raised bed planting, furrow irrigation is followed. Care needs to be taken at first irrigation that water should not overflow on the ridges/beds. As a thumb rule, the irrigation should be applied in furrows up to 2/3rd height of the ridges/beds. In raised bed and in limited irrigation water, the irrigation water can also be applied in alternate furrows to save irrigation water. In rainfed conditions, tied-ridges prove helpful in conserving the rainwater, increasing its availability in the root zone for longer period [2, 7, 8, 11].

*4.2.3 Above ground drip irrigation*

High temperature and high evaporative demand during summer season enhances the water requirement of maize crop as a result of which farmers go for a number of irrigation. To increase the water use efficiency of crop, above ground drip irrigation is recommended by Punjab Agricultural University. In this, broad beds are prepared at 1.20 m apart from centre to centre of furrow. These beds are 80 cm wide on the top and 40 cm wide furrows between beds. The beds are covered with U.V stabilized plastic film (Black) of 25 micron thickness (23 grams per $m^2$). Two rows of maize are planted at a spacing of 60 cm keeping plant to plant distance of 20 cm. One lateral pipe is used to irrigate two rows of maize. The drippers are spaced 30 cm apart and are operated at a discharge of 2.2 L per hour as given in **Table 6** [7, 8, 12]. Prevailing climatic regimes of an area affect the efficiency of drip irrigation system [12].

* If discharge rate is different, time of irrigation may be adjusted proportionally by the formula:

$$\text{Time of irrigation} = \frac{2.2 \times \text{Time of irrigation (min.)} *}{\text{Discharge of dripper (l/hr)}} \quad (1)$$

*4.2.4 Sub-surface drip irrigation*

In field experiments, sub surface drip irrigation and fertigation resulted in 18.4% higher system productivity with saving of 28.5% applied irrigation water. Sub-surface irrigation technology can be followed in maize-wheat-summer moong

| Month | Timing of irrigation (min) |
|---|---|
| February | 22 |
| March | 64 |
| April | 120 |
| May | 130 |

**Table 6.**
*Month-wise timing of above ground drip irrigation in spring maize.*

| Crop | Month | Timing of irrigation (min) |
|---|---|---|
| Maize | July | 35 |
| | August | 35 |
| | September | 50 |
| | October | 30 |
| Wheat | December | 30 |
| | January | 65 |
| | February | 70 |
| | March | 50 |
| Summer Moong | May | 60 |
| | June | 45 |

**Table 7.**
*Month-wise timing of sub-surface drip irrigation in maize-wheat-summer moong cropping system.*

cropping system. For this system, Place drip inline having dripper having 20 cm spacing at 20 cm depth with lateral to lateral spacing of 67.5 cm for sub surface drip irrigation in maize-wheat-summer moong cropping system. Sow one row of maize, two rows of wheat and two rows of summer moong on each drip inline during respective season. If discharge of the dripper is 2.2 L/hour, the schedule given in **Table 7** can be followed for sub-surface drip irrigation in above mentioned cropping system [7, 8, 10].

If discharge rate is different, then time of irrigation may be adjusted proportionally by the formula:

$$= (2.2 \times \text{time of irrigation (minutes)} *) \div \text{dripper discharge (litre/h)} \quad (2)$$

*4.2.5 Partial root drying irrigation*

This technique (**Figure 6**) involves alternate wetting and drying of two halves of root zone of crop plants during consecutive irrigations. The PRD technique was developed on the basis of knowledge of root-to-shoot chemical signaling (can be negative or positive) about soil conditions that regulates the shoot physiology. Alternating is essential for maintaining a constant emission of signals from the root-to-shoot, because prolonged exposure of root to drying soil may cause anatomical changes which reduce the ability of root to sense soil drying and not able to sustain the production of ABA for long time period [10]. Different methods to apply the PRD technique can be separation of root system into two parts with sheet particularly in pots, controlled alternate surface drip irrigation on half part of the


**Figure 6.**
*Field view of partial root drying irrigation technique in maize.*

root zone, controlled alternate subsurface drip irrigation on half part of the root zone or controlled alternate furrow irrigation [10].

### 4.3 Weed management

Maize crop is infested with grassy and broad leaf annual weeds. Among grassy, *Dactyloctenium aegypticum*, *Eleucine indica*, *Setaria glauca*, *Cyanodon dactylon*, *Cyperus rotundus*, *Sorghum helepanse*, *Bracharia rapens* are common. The broad leaf weeds are *Celosia argentia*, *Commelina bengalensis*, *Phylanthis niruri*, *Solanum nigrum*, *Amaranthus viridis*, *Trianthema partulacastrum*. Effective weed management strategies have key role in successful maize cultivation. Adoption of weed control practices during the first 6–8 weeks after planting is crucial because maize crop kept weed free for 30–45 days after planting is almost similar in yield as that kept weed free for entire crop period. The annual yield loss in maize because of weed problems is estimated to be approximately 10%. A number of weed management approached can be followed for weed management in maize crop that can be as follows [2, 7, 8]:

#### *4.3.1 Non-chemical control: manual weeding, mulching*

Non-chemical weed control measures can physical or cultural that means manual removal of weeds from the maize fields. In cultural method, Give two hoeings 15–30 days after sowing with khurpa/kasaula/wheel-hoe/triphali/tractor-drawn cultivator. Mulching is practice of keeping crop residues or plastic sheets on the soil surface within the crop rows. Mulching helps in temperature regulation, water conservation as well weed control in field crops [7, 8].

#### *4.3.2 Chemical control*

Sometimes due to continuous rains during the early stages of maize growth it becomes impossible to enter in the field. Also due to scarce availability of farm labour, the only effective way to control weeds is the use of herbicides. Spray of atrataf 50 WP (atrazine) @ 2 kg/ha on medium to heavy textured soils and 1.25 kg/ha in light soils within 10 days of sowing, using 500 L of water prove propitious in keeping weed population low in maize fields. Spray the herbicide uniformly at recommended rates to minimize residual toxicity to crops sown after maize. Alternatively, spray 262.5 ml/ha laudis 420 SC (tembotrione) in 375 L of water at 20 days after sowing provides effective control of mixed weed flora. For the control of *Cyperus rotundus* (dila/motha), apply 500 ml/ha 2,4-D amine salt 58 SL as post emergence 20–25 days after sowing in 375 L of water [2, 7, 8].

## 4.4 Nutrient management

### *4.4.1 Integrated nutrient management*

Among the cereal crops, maize in general and specifically hybrids are very responsive to nutrients applied through organic or inorganic means. The rate of application depends on soil nutrient status and cropping system. For realizing required yield, the dose of applied nutrients should be as par the soil supplying capacity and crop demand. As the response of maize crop to organic manures is remarkable so integrated nutrient management (INM) is very important option in maize based systems.

- Apply 10–15 t/ha of good quality farmyard manure per hectare to the maize crop year after year [7, 8].

- Green manure the field, to be put under maize with Dhaincha/Sunhemp/Cowpea. Cowpea/Dhaincha/Sunhemp should be sown during second fortnight of April using 12/20/20 kg seed per acre, respectively. The 50 days old green manure crop should be burried and allowed to decompose for about 10 days before sowing of maize. In case, summer moong crop is grown the straw should be burried before sowing of maize [7, 8].

- Inoculate the maize seed with recommended bio-fertilizer as described earlier. For this, mix half kg packet of recommended consortium bio-fertilizer with 1 L of water and then thoroughly mix it with maize seed on clean pucca floor. Let it dry in shade and sow the seed immediately. Inoculation with bio-fertilizer should be done after treating the seed with fungicide. The seed inoculation with consortium biofertilizer increase grain yield as well as improves soil health [7, 8, 11].

- Paddy straw compost @ 450 kg/ha along with recommended dose of fertilizers can be an alternate to farm yard manure [7, 8].

- As a general recommendation, one could apply 120 kg N, 60 kg $P_2O_5$ and 40 kg $K_2O$ per hectare for hybrids and 80 kg N, 30 kg $P_2O_5$ and 20 kg $K_2O$ per hectare for composites. Drill one third of nitrogen and the entire quantity of phosphorous and potassium at the time of sowing. Top dress one third of nitrogen at the knee-high stage and the remaining one third at the pre tasseling stage. It may be noted that application of nitrogen fertilizer more than recommended dose is no substitute for FYM [7, 8].

- Decreased Zn availability visuals emerge on middle leaves (2nd or 3rd from tip) of plants which include white or light yellow band and reddish veins on both sides of the midrib [7, 8]. Remedial measures are described in **Table 8**:

### *4.4.2 Fertigation*

It refers to simultaneous application of irrigation water and fertilizers by drip irrigation. By this method, FUE can go up to 80%. In drip irrigation model for spring maize, certain recommendations are made in respect to fertilizer application along with drip irrigation. For the medium fertility soils application of 200 kg of urea, 80 kg of mono ammonium phosphate (MAP) and 40 kg of muriate of potash (white)/ha is recommended. Start fertigation 12 days after sowing of maize and apply 25% of the fertilizers in four equal splits during first month on weekly basis. Rest of the fertilizer should be applied in equal splits on weekly basis upto first week of May. Furthermore,

| Method of application | $ZnSO_4$ (33%) | $ZnSO_4$ (21%) |
|---|---|---|
| Broadcasting | 16.25 kilogram/ha | 25 kilogram/ha |
| Foliar application | 1.88 + 0.94 kilogram unslaked lime | 3 + 1.5 kilogram unslaked lime |

**Table 8.**
*Remedial measures for Zn deficiency in maize.*

in sub-surface drip irrigation, fertilizer can be applied to maize crop when grown in maize-wheat-summer moong cropping system. For instance, Apply sub surface drip irrigation at 3 days interval for maize and summer moong with fertigation of 80% recommended dose of NPK. In maize, apply 1/5 dose of NPK at sowing and fertigate remaining P and K in 5 splits and N in 7 splits at 9 days interval starting from 15 DAS. Apply sub surface drip irrigation at 7 days interval up to mid-February and thereafter at 5 days interval to wheat with fertigation of 80% recommended dose of NPK. In wheat, apply 1/5th dose of NPK at sowing and fertigated the remaining NPK in 8 splits at 7 days interval starting from crown root initiation. In summer moong, fertigated NPK dose in 5 equal splits at 6 days interval starting from 10 DAS. Use urea, mono ammonium 119 phosphate and muriate of potash as source of N, P and K, respectively [7, 8].

## 4.5 Insect and pest management

### *4.5.1 Integrated pest management (IPM)*

IPM (**Figure 7**) is highly efficient and eco-friendly strategy which includes integrated use of all possible alternates that can be biological, physical, cultural or chemical for controlling pests. Growers who are aware of the potential for pest infestation follow a four-tiered approach. The four steps include: set action thresholds, monitor and identify pests, prevention and control [11, 13].

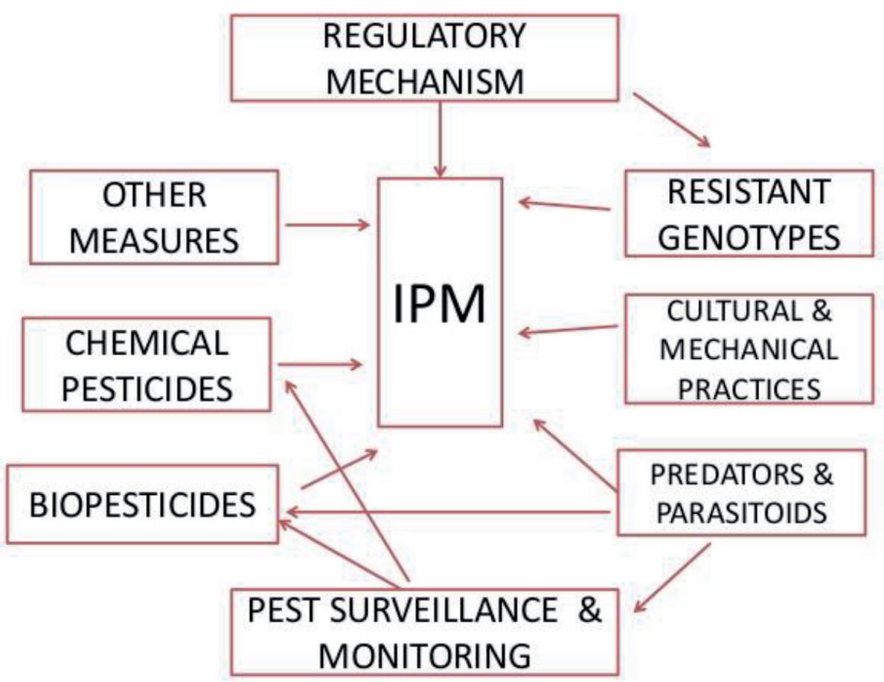


**Figure 7.**
*Components of IPM.*

- **Cultural control**: Deep summer plowing helps in destroying resting stage of pests. Inter-cropping with legume reduces borer incidence. Use of well decomposed farm yard manure termite attack. Balanced use of fertilizers.

- **Genetic management**: Use of good quality planting material from reliable source.

- **Mechanical control**: Cutting and destroying infected plants which ceases further spread. Use of pheromone traps. Set up of light traps.

- **Chemical control**: use of synthetic chemicals for the control of insect-pest and diseases [13].

*4.5.2 Biological pest management*

This approach encompasses use of living entities for the control of insect-pests and diseases. Living entities can be predators, herbivores or parasites along with intensive human interference. For controlling maize borer and other insects, apply bio-insecticides like Neemazal (1%) @ 300 ml/ha. The maize borer can also be managed by using tricho-cards twice having 40,000 eggs of Corcyra parasitized by *Trichogramma chilonis*. Make first release on 10 days old crop and second 1 week after first release. Cut tricho-cards into 40 equal strips and staple them uniformly on the underside of the central whorl leaves in evening hours. The tricho-cards should not be applied on rainy days [8, 11].

*4.5.2.1 Major insect-pests and diseases*

**Maize stem borer**: This insect (**Figure 8**) attacks the maize crop mainly cultivated during monsoon season. After hatching, larvae enter the stem by scraping followed by boring through whorl. Following strategies can be followed for prevention and protection of crop:

- Summer plowing of field.

- Destruction of perennating stages in stubbles, cobs, stalks.

- Cut and bury the severely infested plant parts.

- Spray the crop 2–3 weeks after sowing as soon as borer injury to the leaves is noticed with Coragen 18.5 SC (chlorantraniliprole) @ 75 ml using 150 L water/ha with knap-sack sprayer [7, 8, 11].

**Shoot fly:** Although it is major pest in Southern India but it may infest the maize crop sown in spring season in Northern India. Mainly it attacks the seedling stage of crop (**Figure 9**) where maggots move down to the basal portion through leaf sheath followed by cutting of growing point resulting in dead hearts. Control measures can be as follow:

- Spring crop should be sown between January 20 and February 15.

- Seed should be treated with gaucho (imidacloprid) 600 FS @ 6 ml/kg seed [7].

**Figure 8.**
*Damage of maize crop by maize stem borer.*

**Figure 9.**
*Attack of shoot fly in maize crop.*

**Hairy caterpillar**: This pest becomes a serious concern when attacks in epidemic form. They damage the crop by feeding on leaves and soft stem, from gregarious (during younger stage) to distant migration (grown up stage). Prevention and protection strateges can be as follow:

- Collection and destruction of young larvae by cutting and burying the attacked plant parts.

- Physical destruction of large caterpillars [2, 3].

**Mite:** The attack of mite is serious in June on the young crop or in September–October when the crop is nearing maturity. The affected leaves turn pale and can be recognized from the presence of dusty webs [7, 8].

*4.5.2.2 Recently reported pest infestations*

In recent years, non-associated pests (**Figures 10** and **11**) have been reported in different parts of India with the details as below (**Table 9**) [3]:

*4.5.2.3 Diseases*

**Seed rot and seedling blight**: Poor germination, unthrifty seedlings and seedling mortality are the symptoms. Use disease free seed [7, 8].

**Figure 10.**
*Attack of army worm in maize crop.*

**Figure 11.**
*Attack of pollen eating beetle on maize tassels.*

| Pest name | Plant part infested | Region |
|---|---|---|
| *Helicoverpa armigera* | Cob | Southern India |
| *Chiloloba acuta* | Pollen | Northern India |

**Table 9.**
*Recently reported pest infestations in maize.*

**Figure 12.**
*Maize crop infested with banded leaf and sheath blight.*

**Figure 13.**
*Maydis leaf blight attack in maize crop.*

**Banded leaf and sheath blight:** Water soaked, straw colored necrotic lesions alternating with dark brown bands develop on basal leaf sheaths (**Figure 12**). Lesions enlarge and coalesce with each other. Later, sclerotia develop on diseased sheaths, husk and cobs. In severe cases, developing ears are completely damaged and dry up prematurely with cracking of husk. To manage this disease, spray 250 ml Amistar Top 325 SC (azoxystrobin + difenoconazole) in 200 L of water/ha at disease appearance. If needed, repeat the spray at 15 days interval [1–3].

**Maydis leaf blight**: Symptoms of the disease involve spindle shaped, brownish lesions on the leaves which can further merge to emerge as irregular patches (**Figure 13**). Late sowing, high humidity (>80%) and temperature of 25 + 2°C

**Figure 14.**
*Maize crop attacked by brown stripe downy mildew.*

favors the development of disease. Destroy the infected crop residue in the field. Grow improved varieties. Follow spray schedule as against Brown stripe downy mildew [7, 8].

**Bacterial stalk rot**: Characterized by water soaked appearance and rotting of stem at basal portion causing loss of green color and gives scortching appearance. Rotting of stem results in emitting of foul odor and breakage at 2nd/3rd basal internodes. Excessive rains and poor drainage favors the disease. The infected plants wilt. Destroy the diseased plant debris, keep the fields well drained and use improved varieties for its control [7, 8].

**Brown stripe downy mildew**: Presence of long, brown colored, interveinal stripes on leaves (**Figure 14**), which if critically watched, have white cottony fungal growth on the lower side of leaves. Whitish downy fungal growth may be observed on close examination on underside of the stripes. Control measures can be as follow:

- Removal of secondary host, that is, *Digitaria sanguinalis*.
- Proper drainage of the fields.
- Spray mancozeb @ 500 g/ha in 250 L of water after about a fortnight of sowing. Give two more sprays at 10-day intervals. Grow recommended varieties [7, 8, 11].

### 4.6 Harvesting

For use as grain, cobs should be harvested when grains are at about 20% moisture. Whereas to consume as sweet corn, harvesting should be done when tassel starts turning brown and swelling of cob initiates. In case of baby corn, harvest young cob when the silk is near emergence [6].

### 4.7 Multiple cropping

System in which >2 crops are cultivated in proper sequence on given piece of land during a year. Efficiency of the system is determined by a number of factors namely, manpower, choice of crop/cultivar, availability of irrigation facilities etc.

technical competence, need based farm activities play a critical role in performance of multiple cropping. Following strategies can be adopted for successful adoption of intensive cropping:

- Nursery raising
- Selecting short duration cultivars
- Minimum/no tillage etc. [7, 8].

*4.7.1 Intercropping*

Maize crop can be cultivated along with other crops as intercrops for better utilization of resources, enhanced income per unit area and time basis. For instance, intercropping of 1 row of fodder cowpea or maize, groundnut and soybean in *kharif* maize sown in 60 cm × 20 cm crop geometry. Apply nutrients to maize as per recommendation and to intercrops on the basis of area under cultivation. Harvest fodder cowpea and maize at about 55 DAS. Furthermore, maize crop can also be cultivated as intercrop in *kharif* blackgram. In this system, maize may be intercropped at every fifth row in the 30 cm apart rows of mash crop. Soybean can be successfully intercropped with maize by sowing one line of soybean between two lines of maize sown at 60 cm [8].

*4.7.2 Maize based cropping systems*

Crops like wheat, paddy, potato, sugarcane, chickpea, berseem, barley, oats etc. can be grown successfully after harvest of maize crop. Following are some of the most appropriate maize based cropping systems [2, 8]:

- Cowpea/pearl millet/maize (fodder)
- Spring maize-basmati-wheat
- Maize/rice-wheat
- Maize/rice-potato-wheat
- Maize-potato/*toria*-sunflower
- Maize-potato-onion
- Maize-potato-mentha
- Maize-wheat/celery-pearl millet fodder
- Maize/rice-*gobhi sarson*-summer greengram
- Maize-vegetable pea/potato-spring maize
- Maize-potato-sugarcane-wheat
- Maize-wheat-sugarcane

### 4.8 Techniques to get higher market price

*4.8.1 Maize drying*

Maize drying is a vital operation which involves removal of moisture from the cobs/grains. It is carried out because high moisture grain will deteriorate rapidly due to grain respiration and heating, germination of grains, mold (fungal) growth and subsequent incidence of mycotoxins (e.g. aflatoxin) and increase insect multiplication and damage. The optimum moisture content of maize should be 14% or less [14].

*4.8.1.1 Types of drying*

- **Sun drying:** It is a popular method of drying grain where spread grain is exposed to direct sunlight until the desired grain moisture content is achieved. It is low energy cost.

- **Smoking:** The insect infestation is reduced when hung above the fire as the heat reduces the moisture content and the chemicals in smoke deters insect from laying eggs.

- **Air drying:** The maize cobs are hung along the roof of the house to expose it to air and hence the moisture content is minimized [5].

A portable maize dryer 3 ton capacity has been developed by Punjab Agricultural University, Ludhiana as per international norms and recommended to dry maize grains from a moisture level 25 to 15% in 8–10 hours. This cross-flow dryer has three pass, indirect type diesel fired heating system. A control panel to regulate and display the temperature of heated air, exit air and speed of air blower with variable frequency drive is provided for better operation. The dryer can maintain air temperature 60–75°C with the grain temperature of 45°C for seed and 60°C for commercial purpose. The dryer is capable of drying maize grain @ 1.0–1.5% per hour consuming about 4 L/hour. of diesel initially for 1 hour. A provision of heat recovery from flue gases ensures higher fuel efficiency with reduced diesel consumption to about 2 L/hour, later on. The dryer can be operated both with tractor PTO or electricity. One each of skilled and unskilled labor is required to operate this dryer [8].

## 5. Conclusion

- Adoption of production techniques namely, selection of cultivars, irrigation techniques, INM. IPM and other technological interventions certainly prove propitious in achieving the potential yield targets.

- Maize crop provides better opportunity to scientific community in exploration of resource conservation technologies like zero tillage, partial root drying irrigation, integrated pest management etc.

- Characteristically, maize crop can fit well in diverse crop rotations and intercropping options, which enhances its preference in intensive agriculture.

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## A. Appendix. Common nutrient deficiency symptoms in maize

Nitrogen deficiency

Phosphorus deficiency

Potassium deficiency

Zinc deficiency

Iron deficiency

Magnesium deficiency


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