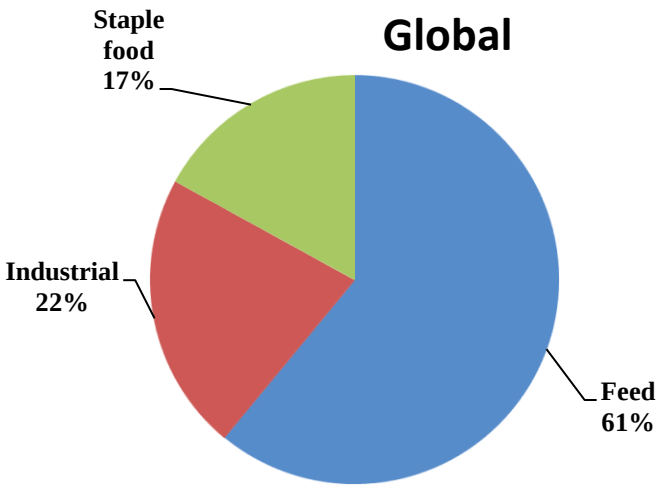
Maize Production Technologies in India

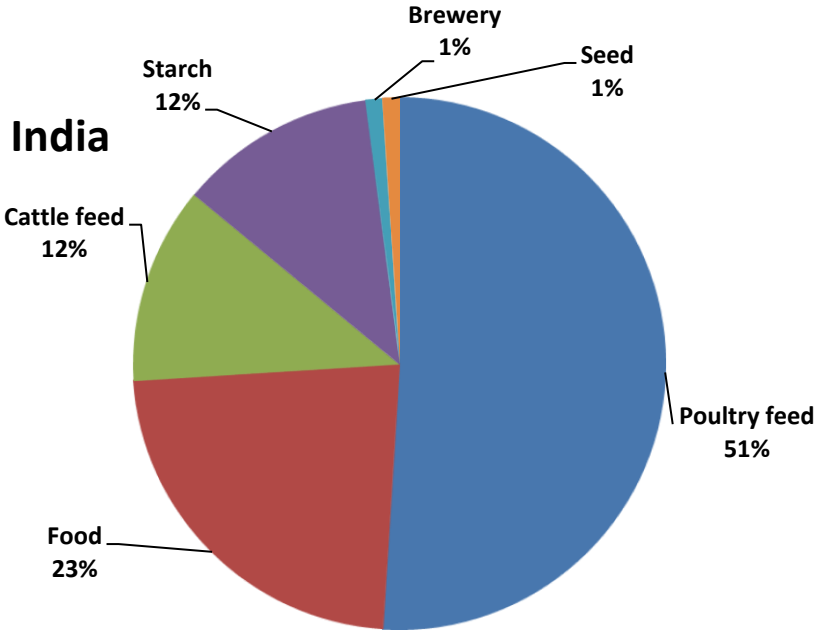
1. Introduction

Maize (*Zea mays* L) is one of the most versatile emerging crops having wider adaptability under varied agro-climatic conditions. Globally, maize is known as queen of cereals because it has the highest genetic yield potential among the cereals. It is cultivated on nearly 150 m ha in about 160 countries having wider diversity of soil, climate, biodiversity and management practices that contributes 36 % (782 m t) in the global grain production. The United States of America (USA) is the largest producer of maize contributes nearly 35 % of the total production in the world and maize is the driver of the US economy. The USA has the highest productivity ($\geq$ 9.6 t ha^{-1}) which is double than the global average (4.92 t ha^{-1}). Whereas, the average productivity in India is 2.43 t ha^{-1}.

In India, maize is the third most important food crops after rice and wheat. According to advance estimate it is cultivated in 8.7 m ha (2010-11) mainly during *Kharif* season which covers 80% area. Maize in India, contributes nearly 9 % in the national food basket and more than Rs. 100 billion to the agricultural GDP at current prices apart from the generating employment to over 100 million man-days at the farm and downstream agricultural and industrial sectors. In addition to staple food for human being and quality feed for animals, maize serves as a basic raw material as an ingredient to thousands of industrial products that includes starch, oil, protein, alcoholic beverages, food sweeteners, pharmaceutical, cosmetic, film, textile, gum, package and paper industries etc.

Recent trends (2003-04 to 2008-09) in growth rate of area (2.6 %), production (6.4 %) and productivity (3.6 %) of maize in India has been of high order and experienced highest growth rate among the food crops. Since 1950-51, the area, production and productivity of maize have increased by more than 3.4, 12 and 4.5 times from 3.2 m ha, 1.7 m t and 547 kg ha^{-1} to current level of 8.17 m ha, 19.33 m t and 2414 kg ha^{-1}, respectively due to increasing maize demand for diversified uses. In India, the maize is used as human food (23%), poultry feed (51 %), animal feed (12 %), industrial (starch) products (12%), beverages and seed (1 % each). With the increasing trends of maize production, the projected demand of maize (22.73 m t) by the end of XI^{th} five year plan (2011-12) will be achieved through improved maize production technologies focused on 'Single Cross Hybrids'.


Global
Staple food 17%
Industrial 22%
Feed 61%


India
Brewery 1%
Seed 1%
Starch 12%
Cattle feed 12%
Poultry feed 51%
Food 23%

Current maize utilization pattern

The maize is cultivated throughout the year in all states of the country for various purposes including grain, fodder, green cobs, sweet corn, baby corn, pop corn in peri-urban areas. The predominant maize growing states that contributes more than 80 % of the total maize production are Andhra Pradesh (20.9 %), Karnataka (16.5 %), Rajasthan (9.9 %), Maharashtra (9.1 %), Bihar (8.9 %), Uttar Pradesh (6.1 %), Madhya Pradesh (5.7 %), Himachal Pradesh (4.4 %). Apart from these states maize is also grown in Jammu and Kashmir and North-Eastern states. Hence, the maize has emerged as important crop in the non-traditional regions i.e. peninsular India as the state like Andhra Pradesh which ranks 5th in area (0.79 m ha) has recorded the highest production (4.14 m t) and productivity (5.26 t ha^{-1}) in the country although the productivity in some of the districts of Andhra Pradesh is more or equal to the USA.

2. Soils

Maize can be grown successfully in variety of soils ranging from loamy sand to clay loam. However, soils with good organic matter content having high water holding capacity with neutral pH are considered good for higher productivity. Being a sensitive crop to moisture stress particularly excess soil moisture and salinity stresses; it is desirable to avoid low lying fields having poor drainage and also the field having higher salinity. Therefore, the fields having provision of proper drainage should be selected for cultivation of maize.

3. Time of sowing

Maize can be grown in all seasons viz; *Kharif* (monsoon), post monsoon, *Rabi* (winter) and spring. During *Rabi* and spring seasons to achieve higher yield at farmer's field assured irrigation facilities are required. During *Kharif* season it is desirable to complete the sowing operation 12-15 days before the onset of monsoon. However, in rainfed areas, the sowing time should be coincided with onset of monsoon. The optimum time of sowing are given below.

Season	Optimum time of sowing
Kharif	Last week of June to first fortnight July
Rabi	Last week of October for inter cropping and up to 15th of November for sole crop
Spring	First week of February

4. Seed rate and plant geometry

To achieve higher productivity and resource-use efficiencies optimum plant stand is the key factor. The seed rate varies depending on purpose, seed size, plant type, season, sowing methods etc. The following crop geometry and seed rate should be adopted.

S. No.	Purpose	Seed rate (kg ha^{-1})	Plant geometry (plant x row, cm)	Plant population
1	Grain (normal and QPM)	20	60 x 20 75 x 20	83333 66666
2	Sweet corn	8	75 x 25 75 x 30	53333 44444
3	Baby corn	25	60 x 20 60 x 15	83333 111111
4	Pop corn	12	60 x 20	83333

5	Green cob (normal maize)	20	75 x 20 60 x 20	66666 83333
6	Fodder	50	30 x 10	333333

5. Seed treatment

To protect the maize crop from seed and major soil borne diseases and insect-pests, seed treatment with fungicides and insecticides before sowing is advisable/ recommended as per the below given details.

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

6. Tillage and crop establishment

Tillage and crop establishment is the key for achieving the optimum plant stand that is the main driver of the crop yield. Though the crop establishment is a series of events (seeding, germination, emergence and final establishment) that depends on interactions of seed, seedling depth, soil moisture, method of sowing, machinery etc but, the method of planting plays a vital role for better establishment of crop under a set of growing situation. Maize is mainly sown directly through seed by using different methods of tillage & establishment but during winters where fields are not remain vacant in time (till November), transplanting can be done successfully by raising the nursery. However, the sowing method (establishment) mainly depends on several factors *viz* the complex interaction over time of seeding, soil, climate, biotic, machinery and management season, cropping system, etc. Recently, resource conservation technologies (RCTs) that include several practices viz. zero tillage, minimum tillage, surface seeding etc. had came in practice in various maize based cropping system and these are cost effective and environment friendly. Therefore it is very important that different situations require different sowing methods for achieving higher yield as described below:

(i) Raised bed (ridge) planting: Generally the raised bed planting is considered as best planting method for maize during monsoon and winter seasons both under excess moisture as well as limited water availability/rainfed conditions. Sowing/planting 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. Moreover, 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. For realizing the full potential of the bed planting technology, permanent beds are advisable wherein sowing can be done in a single pass without any preparatory tillage. Permanent beds are more beneficial under excess soil moisture situations as the infiltration rate is much higher and crop can be saved from the temporary water logging injury.

(ii) Zero-till planting: Maize can be successfully grown without any primary tillage under no-till situation with less cost of cultivation, higher farm profitability and better resource use efficiency. Under such condition one should ensure good soil moisture at sowing and seed and fertilizers should be placed in band using zero-till seed-cum-fertilizer planter with furrow opener as per the soil texture and field conditions. The technology is in place with large number of farmers particularly under rice-maize and maize-wheat systems in peninsular and eastern India. However, use of appropriate planter having suitable furrow opener and seed metering system is the key of success of the no-till technology.

(iii) Conventional till flat planting: Under heavy weed infestation where chemical/herbicidal weed management is uneconomical in no-till and also for rainfed areas where survival of crop depends on conserved soil moisture, in such situations flat planting can be done using seed-cum-fertilizer planters.

(iv) Furrow planting: To prevent evaporative losses of water during spring season from the soil under flat as well as raised bed planting is higher and hence crop suffers due to moisture stress. Under such situation/condition, it is always advisable to grow maize in furrows for proper growth, seed setting and higher productivity.

(v) Transplanting: Under intensive cropping systems where it is not possible to vacate the field on time for planting of winter maize, the chances of delayed planting exists and due to delay planting crop establishment is a problem due to low temperature so under such conditions transplanting is an alternative and well established technique for winter maize. Therefore, for the situation where fields are vacated during December-January, it is advisable to grow nursery and transplant the seedlings in furrows and apply irrigation for optimum crop establishment. Use

of this technique helps in maintenance of temporal isolation in corn seed production areas for production of pure and good quality seed as well as quality protein maize grain. For planting of one hectare, 700 m^2 nursery area is required and the nursery should be raised during second fortnight of November. The age of seedlings for transplanting should be 30-40 days old (depending on the growth) and transplant in the month of December-January in furrows to obtain higher productivity.

7. Nutrient management

Among all the cereals, maize in general and hybrids in particular are responsive to nutrients applied either through organic or inorganic sources. The rate of nutrient application depends mainly on soil nutrient status/balance and cropping system. For obtaining desirable yields, the doses of applied nutrients should be matched with the soil supplying capacity and plant demand (Site-specific nutrient management approach) by keeping in view of the preceding crop (cropping system). Response of maize to applied organic manures is notable and hence integrated nutrient management (INM) is very important nutrient management strategy in maize based production systems. 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 $ZnSO_4$ ha^{-1} is recommended. 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 as per below mentioned for higher N use efficiency.

S. No	Crop Stage	Nitrogen rate (%)
1	Basal (at sowing)	20
2	V_4 (four leaf stage)	25
3	V_8 (eight leaf stage)	30
4	V_T (tasseling stage)	20
5	GF (grain filling stage)	5

Nutrient deficiencies in crops reduce yields, quality and profits to the farmer. Yield can often be reduced 10-30% by deficiencies of major nutrients before any clear symptoms of deficiency are observed in the field. The photographs of common nutrient deficiency symptoms in maize are given in Appendix II.

8. Water management

The irrigation water management depends on season as about 80 % of maize is cultivated during monsoon season particularly under rainfed conditions. However, in areas with assured irrigation facilities are available, depending upon the rains and moisture holding capacity of the soil, irrigation should be applied as and when required by the crop and first irrigation should be applied very carefully wherein water should not overflow on the ridges/beds. In general, the irrigation should be applied in furrows up to $2/3^{rd}$ height of the ridges/beds. Young seedlings, knee high stage (V_8), flowering (V_T) and grain

filling (GF) are the most sensitive stages for water stress and hence irrigation should ensured at these stages. In raised bed planting system and limited irrigation water availability conditions, the irrigation water can also be applied in alternate furrow to save more irrigation water. In rainfed areas, tied-ridges are helpful in conserving the rainwater for its availability in the root zone for longer period. 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.

9. Weed Management

Weeds are the serious problem in maize, particularly during *kharif* /monsoon season they competes with maize for nutrient and causes yield loss up to 35 %. Therefore, timely weed management is needed for achieving higher yield. Atrazine being a selective and broad-spectrum herbicide in maize checks the emergence of wide spectrum of weeds. Pre-emergence application of Atrazine (Atratraf 50 wp, Gesaprim 500 fw) @ of 1.0-1.5 kg a.i ha^{-1} in 600 litre water, Alachlor (Lasso) @ 2-2.5 kg a.i ha^{-1}, Metolachlor (Dual) @ 1.5-2.0 kg a.i ha^{-1}, Pendamethalin (Stomp) @ 1-1.5 kg a.i. ha^{-1} are effective way for control of many annual and broad leaved weeds. While spraying, following precautions should be taken care by the person during spray, he should move backward so that the Atrazine film on the soil surface may not be disturbed. Preferably three boom flat fan nozzle should be used for proper ground coverage and saving time. One to two hoeing are recommended for aeration and uprooting of the remaining weeds, if any. While doing hoeing, the person should move backward to avoid compaction and better aeration. For areas where zero tillage is practiced, 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.

The photographs of the common weed flora in maize are given in Appendix III.

10. Crop protection

A. Insect-pest management

i. Stem Borer (*Chilo partellus*)

Major pest of maize in India is Stalk borer. *Chilo partellus*, popularly known as stalk borer that occurs during monsoon season is a major pest throughout the country. *Chilo* lays eggs 10-25 days after germination on lower side of the leaves. The larva of the *Chilo* enters in the whorl and cause damage in the leaves

ii. Pink Borer (*Sesamia inference*)

Sesamia inference occurs during winter season particularly in peninsular India. The moth of the *Sesamia* is nocturnal and lays eggs on lower leaf sheath. The larvae of the *Sesamia* enter the plant near the base and cause damage to stem.

Control of *Chilo and Sesamia*: For control of *Chilo and Sesamia*, foliar spray of 0.1 % Endosulfan {700 ml (35 EC) in 250 litre water} 10 days after germination is very effective. The *Chilo* can also be controlled by release of 8 Trichocards (*Trichogramma chilonis*) per hectare at 10 days after germination. Intercropping of maize with suitable varieties of cowpea is an eco-friendly option for reducing the incidence of *Chilo* on maize.

iii. Shoot fly *(Atherigona* sp.)

In South India it is a serious pest but it also appears on spring and summer maize crop in North India. It attack mainly at seedling stage of the crop. The tiny maggots creep down under the leaf sheaths till they reach the base of the seedlings. After this they cut the growing point or central shoot which results in to dead heart formation.

Control of Shootfly:

- Sowing must be completed before first week of February so that the crop will escape shootfly infestation.
- Spring sowing must be accompanied with seed treatment with Imidacloprid @ 6ml/kg seed.

iv. Termites *(Odontotermes obesus*)

Termite is also an important pest in many areas. For control of termite fepronil granules should be applied @ 20 kg ha^{-1} followed by light irrigation. If the termite incidence is in patches, than spot application of fepronil @ 2-3 granuled/plant should be done. Clean cultivation delays termite attack.

v. Other emerging pests:

Recently some other non-traditional pests are also causing damage to maize crop viz. larvae of American Bollworm (*Helicoverpa armigera*) which causes damage to cob in Southern part of India while the Chaffer beetle (*Chiloloba acuta*) feeds on maize pollen which adversely affects pollination in northern part of India.

American bollworm

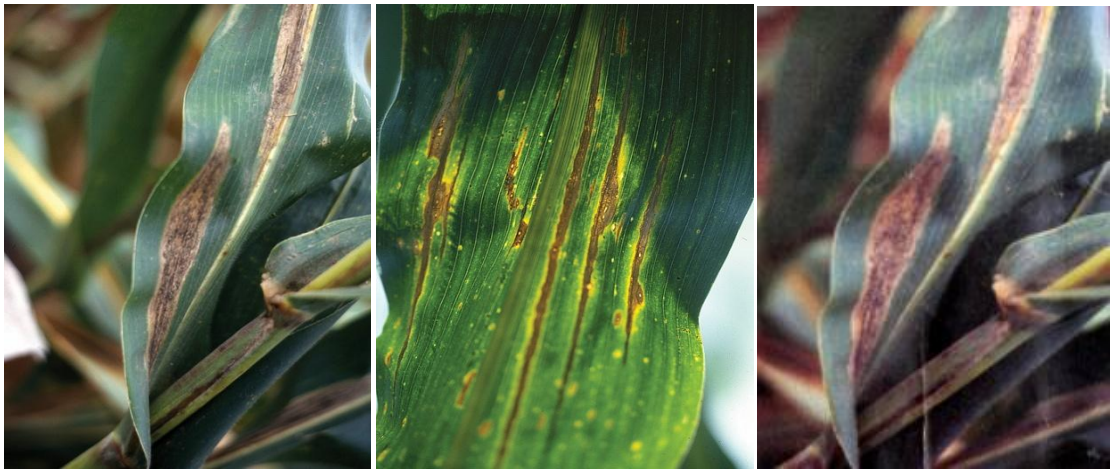
Chaffer beetle

B. Disease management

Across the country several diseases occurs during different seasons, if they are not managed at proper time than they leads to yield loss. BLSB, Pythium stalk rot, Bacterial stalk rot, PFSRs, Polysora rust and Downy mildews are the major constraints to be tackled for realizing genetic potential yield of the crop. Estimated losses due to major diseases of maize in India is about 13.2% of which foliar diseases (5 %), stalk rots, root rots, ear rots (5 %) cause major yield losses. The major diseases and their management practices are described as below:

i. Turcicum leaf blight (*Exserohilum turcicum*)

The disease is prevalent in cooler condition with high humidity of Jammu & Kashmir, Himachal Pradesh, Sikkim, West Bengal, Meghalaya, Tripura, Assam, Rajasthan, Uttar Pradesh, Uttarakhand, Bihar, Madhya Pradesh, Gujrat, Maharashtra, Andhra Pradesh, Karnataka and Tamil Nadu. Long, elliptical, grayish green or tan lesions (2.5-15 cm) appear on lower leaves progressing upward. Grow PEMH-5, Vivek 21, Vivek 23, Vivek 25, Pratap Kanchan 2, Nithyashree in the recommended areas followed by need based sprays of mancozeb @ 2.5 g/litre (with adjuant @ 0.05%) at 8-10 days interval.



ii. Maydis leaf blight (*Drechslera maydis*)

It is a major disease in the states of Jammu & Kashmir, Himachal Pradesh, Sikkim, Meghalaya, Punjab, Haryana, Rajasthan, Delhi, Uttar Pradesh, Bihar, Madhya Pradesh, Gujrat, Maharashtra, Andhra Pradesh, Karnataka and Tamil Nadu having warm humid temperate to tropical climate in the cropping period. Lesions on the leaves elongated between the veins, tan with buff to brown or dark reddish brown borders. Lesion size may vary in inbreds and hybrids due to different genetic backgrounds. Growing of HM 10, PAU 352, Malviya Hybrid Makka 2, EMH 1, HQPM 7, HQPM 5, HQPM 1, Shaktiman 3, Shaktiman 4, PEMH– 5, HQPM-4, and HSC-1 with need based sprays of mancozeb or zineb @ 2.5g/litre of water.

iii. Common rust (*Puccinia sorghi*)

This rust attacks in the maize growing areas with subtropical temperate and high land environment of Jammu & Kashmir, Himachal Pradesh, Sikkim, Meghalaya, West Bengal, Punjab (Rabi), Haryana (Rabi), Rajasthan, Uttar Pradesh, Bihar (Rabi), Madhya Pradesh, Maharashtra, Andhra Pradesh, Karnataka and Tamil Nadu. It appears at the time of tasseling. The circular to elongate, golden brown to cinnamon brown pustules are visible over both leaf surfaces changing to brownish black at plant maturity. Adopt promising hybrids/ varieties viz.; Buland, Sheetal, HHM 1, HHM 2 and HQPM 1, Nithyashree. Spray of mancozeb@ 2.5g/litre of water at first appearance of pustules. Prefer early maturing varieties.

iv. Polysora Rust (*Puccinia polysora*)

It is reported from coastal areas of A.P. and Karnataka where mild temperature and high relative humidity prevail. Light cinnamon golden brown circular to oval pustules appear on leaf densely spread on the upper surface of leaf. Development of pustules on lower surface is more as compared to upper surface. The maize composites namely NAC-6002 (early maturity) and NAC-6004 (late maturity) and the hybrid Hema (NAH–1137), Nithyashree (NAH–2049) and Deccan–105 were resistant to Polysora rust disease of maize. Hence these can be recommended for cultivation in affected areas of AP and Karnataka.

v. Banded leaf and sheath blight (*Rhizoctonia solani* f. sp. *Sasakii***)**

This disease mainly occurs in Jammu and Kashmir, Himachal Pradesh, Sikkim, Punjab, Haryana, Rajasthan, Madhya Pradesh, Delhi, Uttar Pradesh and Bihar. At appearance of the disease, white lesions develops on leaves and sheath. Purplish or brown horizontal bands present on white lesions cThis disease is appearing in severe form in hot humid foothill region in Himalayas and in plains covering states of Jammu & Kashmir, Himachal Pradesh, Almora, Sikkim, Meghalaya, Assam, Nagaland Punjab, Haryana, Rajasthan, Madhya Pradesh, Delhi, Uttar Pradesh and Bihar.The disease appears on leaves and sheaths on 40-50 days old plants and later on spread to the ears. The characteristic lesions appear as concentric bands and rings on lower leaves and sheaths (first and second). The affected plant produces large, gray, tan or brown discoloured areas alternating with dark brown bands. Sclerotia later on are formed in these areas. The developing ear is completely damaged and dried up prematurely with cracking of the husk leaves. Brown rotting of the ears may develop which show conspicuous light brown cottony mold with small, round black sclerotia. Stripping of lower 2-3 leaves along with their sheath considerably lowers incidence. Pratap Kanchan 2, Pratap Makka 3, Pratap Makka 5, Shaktiman 1 and Shaktiman 3 have tolerance to this disease. Seed treatment with peat based formulation @ 16 g/kg of *Pseudomonas fluorescence* or as soil application @ 7g/litre of water, carbendazim, thiophanate-methyl and

captan and foliar spray (30-40 days old crop) of tolcofos-methyl @ 1g/ litre or validamycin @ 2.7ml/litre of water.

vi. Pre-flowering stalk rots (*Pythium aphanidermatum & Erwinia chrysanthemi* p.v. *zeae)*

The high incidence of Pythium and bacterial stalk rots favoured by high temperature and high relative humidity in states of Sikkim, Himachal Pradesh, West Bengal, Punjab, Haryana, Rajasthan, Delhi, Uttar Pradesh, Bihar. In addition, incidence of bacterial stalk rot is also reported from Uttarakhand, Madhya Pradesh and Andhra Pradesh. In Pythium stalk rot, the diseased area of the stalk is brown, water-soaked, soft and collapsed usually confined to a single internode just above the soil line. The plants get twisted due to rotting at infected portion resulting in lodging. In contrast, bacterial stalk rot pathogen can infect the plant at any node from the soil surface up to the whole plant. Primary symptoms of discoloration due to tan to dark brown, water soaked slimy lesions on the leaf sheath and stalk generally appear when plant suddenly falls over and are seen scattered in the field. Splitting of stalk exposes internal discoloration and soft slimy rot at the nodes. A foul odor can be sensed from macerated tissues and the top of such plants can be very easily removed from the rest of the plant. Good field drainage (to avoid waterlogging), planting time between 10 and 20th July in North India, plant population of not more than 50,000/ha reduce the less disease. PEMH- 1, X-1280, HQPM-4, PAU 352, PEMH- 5, DKI – 9202, DKI – 9304 are having tolerance to these stalks. Application of 75% captan @ 12 g/100 litre of water and bleaching powder (33% chlorine) @ 10 kg/ha as soil drench help in the control of these stalks.

vii. Post Flowering Stalk Rot of Maize (PFSR)

The PFSR occurs mainly in Rajasthan, Uttar Pradesh, Bihar and Andhra Pradesh. Disease appears when the crop enters in senescence phase. The pathogen commonly affects the roots crown regions and lower internodes. When split open, the stalk shows pink-purple dis-colouration. For effective control of the disease, water stress at flowering should be avoided. Use balance dose of nutrients wherein potassium application helps in minimizing the disease. Use of bio-control agents (*Trichoderma* formulation) in furrows mixed with FYM @ 10g/kg at 10 days prior to its use in the field. It always advisable to practice crop rotation to minimize the disease incidence.

viii. Downy mildews (DM)

This group of the pathogens constitutes one of the most important factors limiting maize production in India. The important species causing downy mildew in maize in India are the Sorghum downy mildew (SDM; ***Peronosclerospora sorghi***), Brown stripe downy mildew (BSDM; *Sclerophthora rayssiae* var. *zeae*) and Rajasthan downy mildew (RDM; *Peronosclerospora*

hetropogoni). BSDM is found in Himachal Pradesh, Sikkim, West Bengal, Meghalaya, Punjab, Haryana, Rajasthan, Uttarakhand, Bihar, Madhya Pradesh and Gujrat; SDM in Gujrat, Maharashtra, Andhra Pradesh, Karnataka, Tamil Nadu and RDM in Rajasthan and surrounding areas. In BSDM, narrow, chlorotic or yellowish stripes with well-defined margins and delimited by the veins appear on leaves. Downy or wooly cottony whitish growth is visible in early morning hours on lower surfaces of the lesions. Chlorotic plants are seen in SDM infected field and the affected area includes the base of the blade with transverse margin and easily defined between diseased and healthy tissue. RDM symptoms are characterized by the pale appearance of bases of second & third diseased leaves of the seedling giving a complete chlorosis or chlorotic strips. Severely infected plants give yellowish appearance even from a distance. Most of the infected plants die at about knee-high stage. The local or secondary symptoms start appearing from 2-3 leaf stage until tassels and silks are formed. Under humid conditions whitish fluffy growth due to abundant fructification of the fungus can be observed on the lower and upper leaf surfaces. Tassels may be malformed producing less pollen while ears may be aborted resulting in partial or complete sterility. In early symptoms plants are stunted and may die. Rogue and destroy infected plants as they appear in the field. Avoid maize-sorghum crop rotation in field where disease has occurred. Avoid sowing of maize adjacent to a field of maize or sorghum to avoid the spread of secondary infection. Early planting of maize escapes RDM infection. Use resistant varieties /hybrids (PAU 352, Pratap Makka 3, Gujarat Makka 4, Shalimar KG 1, Shalimar KG 2, PEMH– 5, Bio 9636, NECH- X-1280, DMH 1, NAC 6002, COH (M) 4, COH (M) 5, Nithyashree. Seed should invariably be treated with metalaxyl @ 2.5g/kg seed and need based foliar sprays of systemic fungicide such as metalaxyl @ 2-2.5g/L is recommended at first appearance of disease symptoms.

11. Maize based cropping systems in India

As maize has wide adaptability and compatibility under diverse soil and climatic conditions and hence it is cultivated in sequence with different crops under various agro-ecologies of the country. Hence, it is considered as one of the potential driver of crop diversification under different situation. Among different maize based cropping systems, maize-wheat ranks 1st having 1.8 m ha area mainly concentrated in rainfed ecologies. Maize-wheat is the 3rd most important cropping systems after rice-wheat and rice-rice that contributes about 3 % in the national food basket. The other major maize systems in India are maize-mustard, maize-chickpea, maize-maize, cotton-maize etc. Recently, due to changing scenario of natural resource base, rice-maize

has emerged a potential maize based cropping system in peninsular and eastern India. In peri-urban interface, maize based high value intercropping systems are also gaining importance due to market driven farming. Further, maize have compatibility with several crops of different growth habit that led to development of various intercropping systems. Studies carried out under various soil and climatic conditions under All India Coordinated Research Project on Cropping Systems revealed that compared to existing cropping systems like rice-wheat and rice-rice, maize based cropping systems are better user of available resources and the water use efficiency of maize based cropping systems was about 100 to 200 % higher at different locations.

Table 1. Maize based sequential cropping systems in different ago-climatic zones of India

Agro-climatic region	Cropping system	
	Irrigated	Rainfed
Western Himalayan Region	Maize-wheat Maize-potato-wheat Maize-wheat-greengram Maize-mustard Maize-sugarcane	Maize-mustard Maize-legumes
Eastern Himalayan Region	Summer rice-maize-mustard Maize-maize Maize-maize-legumes	Sesame-Rice+maize
Lower Gangetic Plain region	Autumn rice-maize Jute-rice-maize	Rice-maize
Middle Gangetic Plain region	Maize-early potato-wheat-mungbean Maize-wheat Maize-wheat-mungbean Maize-wheat-urdbean Maize-sugarcane-mungbean	Maize-wheat
Upper Gangetic Plain region	Maize-wheat Maize-wheat-mungbean Maize-potato-wheat Maize-potato-sunflower Maize-potato-onion Maize-potato-sugarcane-ratoon Rice-potato-maize	Maize-wheat Maize-barley Maize-safflower
Trans Gangetic Plain region	Maize-wheat Maize-wheat-mungbean Maize-potato-wheat Maize-potato-sunflower Maize-potato-onion Mungbean-maize-toria-wheat Maize-potato-mungbean	Maize-wheat
Eastern plateau & hills region	Maize-groundnut-vegetables Maize-wheat-vegetables	Rice-potato-maize Jute-maize-cowpea
Central plateau & hills region	Maize-wheat	Maize-groundnut
Western plateau & hills region	Sugarcane + Maize	

Southern plateau & hills region	Rice-maize Maize-rice	Sorghum-maize Maize-sorghum-Pulses Maize-potato-groundnut
East coast plain and hills region	Rice-maize-pearlmillet Maize-rice Rice-maize Rice-rice-maize	Maize-maize-pearlmillet Rice-maize + cowpea
West coast plain and hills region	Maize-pulses Rice-maize	Rice-maize Groundnut-maize
Gujrat plains and hills region	Maize-wheat	Rice-maize
Western dry region	Maize-mustard Maize-chickpea	Maize+legumes
Island region	Rice-maize	Maize-rice Rice-maize + cowpea Rice-maize-urdbean Rice-rice-maize

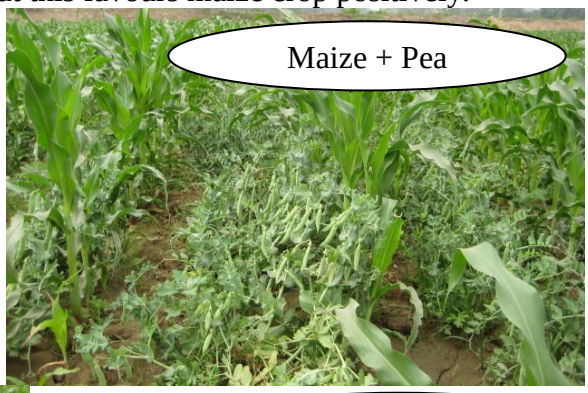
Table 2 Maize based intercropping systems

Intercropping systems	Suitable area/situation
Maize + Pigeon pea Maize + Cowpea Maize + Mungbean Maize + Urdbean Maize + Sugarcane Rice + Maize Maize + Soybean	All maize growing areas
Maize + high value vegetables Maize + flowers Baby corn + vegetables Sweet corn + vegetables	Peri-urban interface

12. Maize and climate change

Under the changing climate scenario the limitations of rising temperature during grain filling of wheat particularly in eastern India, and declining yield of boro rice in West Bengal and Orissa, water scarcity areas in peninsular India (AP and Tamil Nadu) affecting yield of *Rabi* rice, maize being a photo-insensitive crop has better options for adaptation and mitigation of these climatic changes. 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 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 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.



Maize + Carrot

Maize based intercropping systems

Therefore, in view of the changing farming scenario in the country, maize has been emerging as one of the potential crops that addresses several issues like food and nutritional security, climate change, water scarcity, farming systems, bio-fuel etc. Further, a recent study by National Centre for Agricultural Economics and Policy Research (NCAP) has showed that there is an increasing demand for maize in the industry sector which caters to consumer needs like textiles, paper, glue, alcohol, confectionery, food processing and pharmaceutical industry etc., of which the demand keeps on increasing with population pressure.

Appendix I. Maize varieties of different maturity suitable for various states and seasons

A. List of hybrids (H) and composites(C) varieties of different maturity groups for different states for *kharif* season

States	Extra early maturity	Early maturity	Medium maturity	Late maturity
Delhi	H:Vivek 17 &21, PMH 2	H:PAU 352, PEH 3, Parkash, X 3342	H:HM4, HM 8 10, DK 701	H:PMH 3, Buland, NK 61, Pro 311, Bio 9681, Seed Tech 2324
Punjab	H:Vivek 17& 21, PEEH 5	H:PAU 352, PEH 3, JH 3459, Parkash, PMH 2, X 3342	H:HM4, HM 8& 10, DK 701	H:PMH 3, PMH-1 , Buland, Pro 311, Bio 9681 , NK 61, Pro 311, Seed Tech 2324
Haryana	H:Vivek 17 &21, PMH 2, PEEH 5	H:HHM 1,PAU 352, Pusa Early Hybrid 3, JH 3459 Parkash, X 3342	H:HM 2, HM 4,8 &10 DK 701	H:PMH 3, Buland, ,HM 5, NK 61, Pro 311, Bio 9681, Seed Tech 2324
Uttar Pradesh	H:Vivek 5, 15, 17, 21 & 27 PMH 2,	H: JH 3459, Parkash,PEH 2, X 3342 C: Pusa Composite 4,	H:HM 8& 10, Malviya hybrid makka 2, Bio 9637 ,DK 701	H:PMH 3, Buland, Pro Agro 4212, Pro 311, Bio 9681, NK 61,Seed Tech 2324
Rajasthan	H:Pratap hybrid 1, Vivek 4 & 17,	H: PEHM 2 ,Parkash ,Pro 368, X 3342 C: Pratap Makka 3, Aravali Makka 1, Jawahar Makka 8,Amar, Azad Kamal, Pant Sankul Makk 3,	H: HM 10, NK 21 C: Pratap Makka 5	H: Trishulata, Pro 311, Bio 9681, Seed Tech 2324
Madhya Pradesh	H:Vivek 4 & 17	H: PEHM 2, Parkash, Pro 368, X 3342 C: Jawahar Makka 8, Jawahar composite 12, Amar, Azad Kamal, Pant Sankul Makka 3, Chandramani, Pratap Makka 3	H: HM 10, NK 21 C: Pratap Makka 5	H: Trishulata , Pro 311, Bio 9681, Seed Tech 2324
Gujarat	H:Vivek 4 &17	H: PEHM 2, Parkash, Pro 368, X 3342 C: Jawahar Makka 8,Pant Sankul Makka 3, Pratap Makka 3, G M 2,4 & 6 Aravali Makka 1, Narmada Moti	H: HM 10, NK 21 C: Pratap Makka 5	H:Trishulata , Pro 311, Bio 9681, Seed Tech 2324 C: G M 3,
Andhra Pradesh	H:Vivek 9, 15, 17& 27, PEEH 5	H:PEHM 1, PEHM 2, DHM 1, BH- 2187, Parkash, JKMH 1701, X 3342	H:HM 8& 10, DHM111,DHM117	H:DHM113,Kargil 900 M, Seed Tech 2324, Pro 311, Bio 9681, Pioneer 30 v 92, Prabal, 30 V 92,
Tamil Nadu	H:Vivek 9, 15, 17, 21& 27, PEEH 5	H:PEHM 2 , Parkash, X 3342 JKMH 1701	H:HM 8& 10, COHM 4	H:COHM 5, Prabal , Pro 311, Bio 9681, Seed Tech 2324, 30 V 92,
Maharashtra	H:Vivek 9, 15,17, 21& 27, PEEH 5	H: PEHM 1& 2, Parkash, X 3342 , JKMH 1701	H:HM 8& 10	H: Prabal, Pro 311, Bio 9681, Seed Tech 2324, 30 V 92,
Karnataka	H:Vivek 9, 15, 21& 27, PEEH 5	H: PEHM 2 , Parkash, X 3342 JKMH 1701 C: NAC 6002	H:HM 8& 10	H:Nithya Shree,EH434042, DMH 1, DMH 2, Bio 9681, Prabal, Pro 311, Seed Tech 2324 C: NAC 6004, 30 V 92

States	Extra early maturity	Early maturity	Medium maturity	Late maturity
Jammu & Kashmir	H: Vivek 15, 21, 25 &33, PEEH 5 C: Pratap Kanchan 2, Shalimar KG 1 & 2,Vivek 35,and 37	H: Vivek 33, Parkash, JKMH 1701, X 3342 C: C 8,14 & 15	H: HM 10 C: C 6	-
Uttarakhand	H: Vivek 5, 9, 21& 25 PEEH 5 C: Pratap Kanchan 2,Vivek 35 and 37	H:Vivek hybrid 33, Vivek hybrid 23, Parkash	H: HM 10 C: Bajaura Makka	-
Bihar	H: Vivek 27 C: D 994	H: Parkash, X 3342 C: Dewaki, Birsa Vikas Makka 2	H:HM 9, Malviya hybrid makka 2	H: Pro 311, Bio 9681, Seed Tech 2324, 30 V 92, 900 M C: Hemant, Suwan & Lakshmi
Jharkhand	H: Vivek 27 C: D 994,	H: Parkash, X 3342 C: Dewaki, B V M 2, B M 1	H:HM 9, Malviya hybrid makka 2, DK 701	H: Pro 311, Bio 9681, Seed Tech 2324 C: Suwan
Orissa	H: Vivek 27 C: D 994,	H: Parkash, HIM 129, X 3342	H:HM 9, Malviya hybrid makka 2, DK 701, DMH 115, Pro 345	H: , Pro 311, Bio 9681, Seed Tech 2324 , PAC 705
West Bengal	H:Vivek 27	H: Parkash, X 3342	H:Malviya hybrid Makka 2	H: Pro 311, Bio 9681, Seed Tech 2324
Himachal Pradesh	H:Vivek 15, 21& 25, PEEH 5	H: Parkash, X 3342	C: Bajaura Makka, Pratap Makka 4	H: Pro 311, Bio 9681, Seed Tech 2324
NEH Region	H:Vivek 21& 25, PEEH 5	H: Parkash , JKMH 1701, X 3342	C: Pratap Makka 4	H: Pro 311, Bio 9681, Seed Tech 2324 C: NLD white
Chhattisgarh	H:Vivek 27	H: Parkash, X 3342	C: Pratap Makka 5	H:PEHM 1, Pioneer 30 V 92 & 30 R 26, Bio 9681, Pro 4640 & 4642,
Assam	-	H:Parkash, X 3342	H: DK 701 C: Pratap Makka 4	C: Vijay ,NLD white,

B. 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 **Rajasthan**	H: PMH 3, Buland, Pro Agro 4212, Pro 311, Bio 9681, NK 61,Seed Tech 2324,HM8 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
Jammu & Kashmir	-
Uttarakhand	-
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
Orissa	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,

C. List of hybrids (H) and composites(C) varieties of different maturity groups for different states for *spring* season

States	Extra early maturity	Early maturity
Delhi	H:Vivek 17 &21, PMH 2	H: PAU 352, PEH 3, Parkash, X 3342
Punjab	H:Vivek 17& 21, PEEH 5	H:PAU 352, PEH 3, JH 3459, Parkash, PMH 2, X 3342
Haryana	H:Vivek 17 &21, PMH 2, PEEH 5	H: HHM 1,PAU 352, Pusa Early Hybrid 3, JH 3459 Parkash, X 3342
Uttar Pradesh	H: Vivek 5, 15, 17, 21 & 27 PMH 2,	H: JH 3459, Parkash,PEH 2, X 3342, C: Pusa Composite 4, Gaurav, Azad Uttam, Surya, Kiran, Tarun
Rajasthan	H:Pratap hybrid 1, Vivek 4 & 17,	H: PEHM 2 ,Parkash ,Pro 368, X 3342 C: Pratap Makka 3, Aravali Makka 1, Jawahar Makka 8, Amar, Azad Kamal, Pant Sankul Makk 3, Mahi Kanchan, Mahi Dhawal
M.P.	H: Vivek 4 & 17	H: PEHM 2, Parkash, Pro 368, X 3342 C: Jawahar Makka 8, Jawahar composite 12, Amar, Azad Kamal, Pant Sankul Makk 3, Chandramani, Pratap Makka 3
Gujarat	H: Vivek 4 &17	H: PEHM 2, Parkash, Pro 368, X 3342 C: Jawahar Makka 8,Pant Sankul Makka 3, Pratap Makka 3, G M 2,4 & 6 Aravali Makka 1, Narmada Moti
Andhra Pradesh	H: Vivek 9, 15, 17& 27, PEEH 5	H:PEHM 1, PEHM 2, DHM 1, BH- 2187, Parkash, JKMH 1701, X 3342
Tamil Nadu	H: Vivek 9, 15, 17, 21& 27, PEEH 5	H: PEHM 2 , Parkash, X 3342
Maharashtra	H:Vivek 9, 15,17, 21& 27, PEEH 5	H: PEHM 1& 2, Parkash, X 3342 , C:, JKMH 1701
Karnataka	H:Vivek 9, 15, 21& 27, PEEH 5	H: PEHM 2 , Parkash, X 3342, C: NAC 6002
Jammu & Kashmir	H: Vivek 15, 21, 25 &33, PEEH 5 C: Pratap Kanchan 2, Shalimar KG 1 & 2	H: Vivek 33, Parkash, JKMH 1701, X 3342, C: C 8,14 & 15
Uttarakhand	H: Vivek 5, 9, 21& 25 PEEH 5 C: Pratap Kanchan 2	H:Vivek hybrid 33, Vivek hybrid 23, Parkash
Bihar	H: Vivek 27 C: D 994, Gujarat Makai 6	H: Parkash, X 3342, C: Dewaki, Birsa Vikas Makka 2
Jharkhand	H: Vivek 27, C: D 994,	H: Parkash, X 3342, C: Dewaki, B V M 2, B M 1
Orissa	H: Vivek 27, C: D 994,	H: Parkash, HIM 129, X 3342
West Bengal	H: Vivek 27	H: Parkash, X 3342
Himachal Pradesh	H: Vivek 15, 21& 25, PEEH 5	H: Parkash, X 3342, C:
NEH Region	H: Vivek 21& 25, PEEH 5	H: Parkash ,JKMH 1701, X 3342
Chhattisgarh	H:Vivek 27	H:Parkash, X 3342
Assam	-	H:Parkash, X 3342

Appendix II. Common nutrient deficiency symptoms in maize

Nitrogen Deficiency

Phosphorus Deficiency

Potassium Deficiency

Zinc Deficiency

Sulphur Deficiency

Copper Deficiency

Iron Deficiency

Magnesium Deficiency

Manganese Deficiency

Appendix III. Common weed flora in maize

1. **Narrow Leaved Weeds:**

Sanva (*Echinochloa crusgalli*)

Goosegrass (*Acrachne racemosa*)

Crowfootgrass (*Eleusine indica*)

Viper grass (*Dinebra retroflexa*)

Dactyloctenium aegyptium

Green bristlegrass (*Setaria viridis*)

Banchari (*Sorghum halepense*)

Bandra (*Setaria glauca*)

Doob (*Cynodon dactylon*)

Narkul (*Phragmites karka*)

Crabgrass (*Digitaria sanguinalis*)

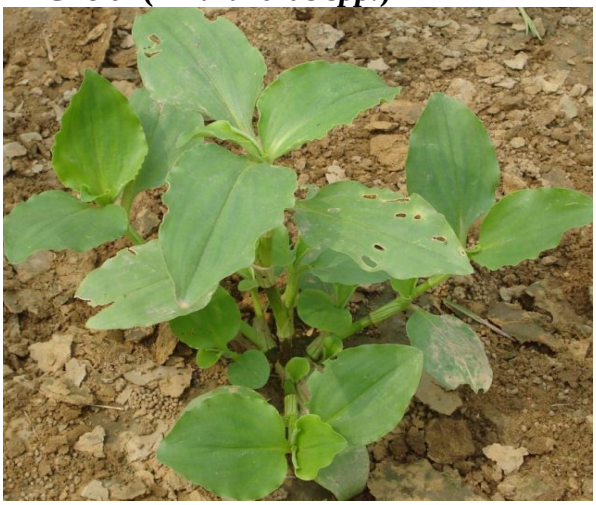
Little Lovegrass (*Eragrostis tenuifolia*)

2. Broad Leaved Weeds:

Kundra (*Digera arvensis*)

Cholai (*Amaranthus spp.*)

Desert horsepurslane (*Trianthema portulacastrum*)



Day Flower (*Commelina benghalensis)*

Hazardana(Phyllanthus niruri)

Jungli Jute (*Corchorus acutangulus*)

White cock's comb (*Celosia argentina*)

Black Nightshade (*Solanum nigrum*)

Hulhul (*Cleome viscosa*)

Puncture vine (*Tribulus terrestris*)

Congress grass (*Parthenium hysterophorus*)

Wildflower (*Xanthium strumarium)*

Creeping Woodsorrel (*Oxalis corniculata*)

Chikweed (***Stellaria media***)

Gajari (*Fumeria parviflora*)

Lambsquarters (***Chenopodium album***)

3. Sedges:

Motha (*Cyprus rotondus*)

Yellow nutsedge (C*yprus esculentus*)