GOVERNMENT OF THE PUNJAB
AGRICULTURE DEPARTMENT

MANUAL

MAIZE CULTIVATION
WITH
HIGH EFFICIENCY IRRIGATION SYSTEM (HEIS)



Directorate General Agriculture (Water Management)
Punjab, Lahore

CamScanner

AGRICULTURE DEPARTMENT
GOVERNMENT OF THE PUNJAB

MANUAL

MAIZE CULTIVATION

WITH

HIGH EFFICIENCY IRRIGATION SYSTEM (HEIS)

Directorate General Agriculture (Water Management)
Punjab, Lahore

CamScanner

Table of Contents

Table of Contents i
List of Tables iv
List of Figures v
Abbreviations and Acronyms vii
Preface viii

1. IMPORTANCE 1
1.1. General 1
1.2. Human Food 1
1.3. Animal Feed 2
1.4. Industrial Use 2
1.5. Bio Fuel 2
2. AGRO-ECOLOGICAL ADAPTATION AND CLIMATIC REQUIREMENTS 3
2.1. Agro-ecological Adaptation 3
2.2. Temperature 3
2.3. Photoperiodism 3
2.4. Optimum Sowing Period 4
3. SOIL CHARACTERISTICS 5
3.1. Ground Water Depth 5
3.2. Soil Physical Characteristics 5
3.3. Soil Chemical Characteristics 5
3.3.1. Soil pH 5
3.3.2. Soil Nutrients Availability 5
3.3.3. Soil Salinity 5
4. SEED BED PREPARATION 6
4.1. Flat Fields 6
4.2. Ridges 6
4.3. Beds 7
5. VARIETIES OF MAIZE 9
5.1. Open Pollinated Varieties 9
5.2. Hybrids 9
5.2.1. Single Cross 9
5.2.2. Double Cross 9
5.3. Bt Corn 9
5.4. Varieties Currently Recommended 10
5.4.1. Spring Varieties 10
5.4.2. Autumn Varieties 11
5.5. Characteristics of Various Varieties 12
5.5.1. Spring Maize Varieties 12
5.5.2. Autumn Maize Varieties 13
6. SEED RATE AND PLANT POPULATION 14
6.1. Assessment of Seed Rate 14

CamScanner

6.1.1. Germination Percentage 14
6.1.2. Date of Sowing 14
6.1.3. Varietal Considerations 14
6.1.4. Soil Concerns 14
6.1.5. Method of Sowing 14
6.2. Thinning 15
6.3. Optimum Range of Plant Population 15
6.3.1. Production of Grains 15
6.3.2. Silage Preparation 16
6.3.3. Fodder Production 16
7. METHODS OF SOWING 17
7.1. Single Row Cotton Drill 17
7.2. Tractor Drill 17
7.3. Ridges and Dibbling 17
7.5. Beds and Drilling for Drip Irrigation 17
8. PLANTING GEOMETRIES 18
8.1. Geometries under Surface Irrigation 18
8.1.1. Planting on Flat Fields 18
8.1.2. Planting on Ridges 18
8.1.3. Planting on Beds 18
8.2. Geometries under Drip Irrigation 18
8.2.1. Single Row with One Lateral 18
8.2.2. Paired Rows for Drip Irrigation 19
9. GROWTH STAGES OF MAIZE 22
9.1. Significance of Growth Stages 22
9.2. Types of Growth Stages 22
9.2.1. Vegetative Growth Stages 22
9.2.2. Reproductive Growth Stages 25
9.3. Duration of Growth Stages of Maize Crop 28
10. MAIZE CROP WATER REQUIREMENTS 29
10.1. General Deliberations 29
10.2. Rooting Characteristics and Water Uptake Pattern 30
10.3. Irrigation Scheduling for Maize 32
10.3.1. Values of Reference Daily Evapotranspiration 32
10.3.2. Values of Crop Growth Stage Coefficient 32
10.4. Sample Irrigation Schedule for Maize Crop 36
10.5. System capacity for Peak Demand 37
10.6. Water Quality and Maize Crop Response 38
11. NUTRITION AND FERTIGATION OF MAIZE 39
11.1. Nutrients General Requirement 39
11.2. Nutrients Specific Response 40
11.2.1. Primary Elements 40
11.2.2. Secondary Elements 45

CamScanner

11.2.3. Tertiary or Trace Elements 46
11.3. Nutrients Uptake Curves 47
11.3. 1.Primary Elements 47
11.3.2. Uptake of Secondary and Trace Elements 50
11.4. Fertigation Schedule for Maize Crop 52
12. WEEDS OF MAIZE CROP AND THEIR CONTROL MEASURES 54
12.1. Significance 54
12.2. Weeds Competing with Maize Crop 54
12.3. Technical Names of Weeds and Recognition of their Kind 54
12.4. Control Measures for Weeds 57
12.4.1. Cultural Control 57
12.4.2. Mechanical Control 58
12.4.3. Chemical Control 58
13. CROP ROTATION 59
13.1. Annual Rotation Plans 59
13.2. Biennial Rotation Plans 59
14. INSECTS ATTACKING MAIZE CROP 60
14.1. Significance 60
14.2. Mode of Damage of Maize Insects and their Chemical Control 60
14.3. Integrated Pest Management 65
15.1. Significance 67
15.2. Important Diseases and their Chemical Control 67
15.3. Disease Management Principles 70
16. HARVESTING, THRESHING AND STORING 71
16.1. Signs of Maturity and Harvesting 71
16.2. Threshing Cares 71
16.3. Storing Cares 71
17. YIELD 72
17.1. Significance of Important Parameters 72
17.2. Indicators of Good Yield 72
17.3. Maize Yield Estimation 73
17.4. Potential Yield 73
LIST OF REFRENCES 74

CamScanner

List of Tables

Sr. No.	Particulars	Page No.
Table 1.1	Production Trend of Maize Crop in Punjab from Year 2009 – 10 to 2012 – 13	1
Table 5.1	Open pollinated varieties to be sown in spring season	10
Table 5.2	Hybrid varieties sown in spring season	10
Table 5.3	Open pollinated varieties sown in autumn season	11
Table 5.4	Hybrid varieties sown in autumn season	11
Table 8.1	Number of Plants per Acre at three different row spacing under Paired Rows Plantation	20
Table 9.1	Vegetative Growth Stages and Corresponding Activities	23
Table 9.2	Reproductive Growth Stages and Corresponding Activities	25
Table 10.1	Reference Daily Evapotranspiration Values for All Districts of Punjab	33
Table 10.2	Duration of Four Development Stages of Agronomic Crops and Corresponding Kc Values	35
Table 10.3	Sample Irrigation Schedule for Maize Crop grown in District Layyah	36
Table 11.1	Requirement of Nutrients by Corn Crop with 150 bushels (3810 Kg) yield	39
Table 11.2	Nutrient Uptake by Corn Crop for 5842 Kg of Grain Yield/Acre	40
Table 11.3	Sample Fertigation Schedule for Maize Crop	53
Table 12.1	English names, Technical names and general recognition characters of Maize Weeds	55
Table 12.2	Weeds of Maize Crop, Relevant Herbicides and Method of Application	58
Table 14.1	Mode of damage rendered by the insects attacking on maize crop and their chemical control measures	60
Table 15.1	Causing agents of Maize Diseases, mode of damage and control measures	67
Table 17.1	Value of factors of maize production segregated in terms of yield and percentage	72

CamScanner

List of Figures

Sr. No.	Particulars	Page No.
Figure 4.1	Maize sown on Flat Field	6
Figure 4.2	Sowing of Maize on one side of Ridge	7
Figure 4.3	Beds being irrigated for Sowing of Maize Crop	7
Figure 6.1	Relationship of Grain Yield with Plant Population	15
Figure 8.1	Single Row Planting Geometry for Maize Crop under Drip Irrigation	19
Figure 8.2	Paired Rows Plantation of Maize	20
Figure 8.3	Paired rows being irrigated with one lateral	21
Figure 9.1	Different Vegetative Stages of Maize Crop (VE – VT)	24
Figure 9.2	Reproductive Growth Stages of Maize Plant (R1-R6)	27
Figure 10.1	Curve showing relationship of maize plant growth and daily water use	30
Figure 10.2	Root zone and moisture extraction pattern of Maize plant	31
Figure 10.3	Crop Growth Stage Coefficient Curve for Maize	32
Figure 10.4	Corn Crop grown through HEIS duly fulfilling the CWR.	33
Figure 11.1	Symptoms of Nitrogen Deficiency in Maize	41
Figure 11.2	Cardy Meter to test cell sap for NO3 - N	42
Figure 11.3	Symptoms of Phosphorus Deficiency in young maize plant	42
Figure 11.4	(a & b) Symptoms of Potassium Deficiency in Maize	43
Figure 11.5	Comparison of NPK deficient Leaves of Corn with healthy leaf at the top.	44
Figure 11.6	Leaves of Corn reflecting deficiency symptoms of Magnesium, Drought effects, Helminthosporium blight and Toxicity effects of sprayed chemicals	44
Figure 11.7	Effects of shortage of Phosphorus, shortage of Nitrogen, abundance of Nitrogen and Dry weather on silks and kernel development from top to bottom respectively	45
Figure 11.8	Potassium Deficiency Symptoms in Maize Cobs (poorly filled tip at the bottom compared to well filled tips from normal and rich soils)	46
Figure 11.9	Iron Deficiency in Maize as Bright Yellow Interveinal chlorosis and Magnesium Deficiency as striping in leaves	46
Figure 11.10	Zinc Deficiency Symptoms in Maize	47
Figure 11.11	Corn plants need increasing levels of nitrogen from the VE to R6 growth stages absorbing more than 50% before R1 stage.	48

CamScanner

Figure 11.12	Nitrogen Uptake Pattern in maize Plant	48
Figure 11.13	Nitrogen uptake during various growth stages of maize plant. GDD reflects Growing Degree Days which means the number of days the average temperature is above the base temperature of 50^0 F.	49
Figure 11.14	Curves for uptake of Phosphorus by corn.	49
Figure 11.15	Potassium uptake curve for Maize Plant	50
Figure 11.16	Uptake curves of Magnesium, Boron, Zinc, Manganese, Iron and Copper for maize crop.	51
Figure 12.1	Pictures of important weeds of Maize Crop (a-k)	56
Figure 14.1	Attack of Termites (Odontotermes obesus) on Maize	62
Figure 14.2	Shoot fly adult	63
Figure 14.3	Attack of Shoot Fly on Maize Plant	63
Figure 14.4	Damage caused by attack of shoot fly	63
Figure 14.5	a-Army Worm b-Maize crop after attack of Army Worm	63
Figure 14.6	(a & b): Maize Caterpillar attacking maize kernels	64
Figure 14.7	Damage caused by Maize Stem borer	64
Figure 14.8	(a & b): Attack of Maize Stalk Borer	64
Figure 14.9	Maize aphids (a) and (b)	65
Figure 14.10	Two types of Jassids *Amrasca devastans* and *Amrasca biqutella biqutella*	65
Figure 14.11	Other pictures of Aphid (sust tela) and Jassid (Chust tela)	65
Figure 15.1	(a&b): Symptoms of Leaf Blight attack on Maize	68
Figure 15.2	(a) and (b) Symptoms of Helminthosporium Leaf Spot	69
Figure 15.3	Symptoms of Fusarium Stalk Rot on (a) Maize Leaves and (b) Maize Stem	69
Figure 15.4	Mode of damage of stalk rot caused by Pythium spp.	69

CamScanner

Abbreviations and Acronyms

OPV	Open Pollinated Varieties
Bt	Bacillus Thuringiensis
Bu	Bushel (One bushel of maize grains having 15.4 % moisture = 25.4 kg
Et°	Reference Evapotranspiration
GDD	Growing Degree Days

CamScanner

PREFACE

The overall objective of this manual is to share relevant information with growers and professionals on maize cultivation using high efficiency irrigation system. The manual is broad in scope, devoting different sections to diverse but related fundamental principles covering agro ecological adaptations, edaphic factors, sowing methods, varietal differences and plant protection measure. Main emphasis of the manual is, however, to explicitly demonstrate sowing of maize under high efficiency irrigation system. In this context, planting geometry, crop water requirement, fertigations with drip irrigation have been discussed in detail. The underlying concepts in each section focus to demonstrate the best production technology for maize under drip irrigation system. Many of the statements are based on actual field cases and will, therefore, bring the reader closer to the realities in the field.

We have tried to keep the language as simple and straight forward as possible, consistent with accurate representation of the content. We hope that this effort will make content of the book more useful equally for growers and professionals. The editor takes this opportunity to express his appreciation to the authors for the spirit of collaboration and enthusiasm, they have shown at all the stages of endeavor, making it possible to produce the best possible manual with local orientation and illustrations. It is anticipated that the author's practical experience will make this manual as a valuable reference for the practicing professionals and drip irrigating farmers.

CamScanner

1. IMPORTANCE

1.1. General

Maize (*Zea Mays L*) is an important cereal crop world over ranking highest after wheat and rice. It is an edible grain and is sown on approximately 1.4 million acres in Punjab annually with a production of about 2 million MT with an average of 2100 kg per acre. Maize is grown twice a year in Punjab; first as Spring Crop and second as Autumn Crop. Since the introduction of spring maize cultivation, there is gradual increase in planting of maize during spring season in the irrigated low land areas of Punjab. This shift in production trend during last few years is evident from Table 1.1.

Table 1.1: Production Trend of Maize Crop in Punjab from Year 2009 – 10 to 2012 – 13

Year	Area (Thousand Acres)	Total Production (Thousand Tons)	Average Production/ Acre(Kg)
Kharif Crop			
2009 - 10	967	1743	1804
2010 - 11	975	1835	1883
2011 - 12	998	1900	1904
2012 - 13	987	2016	2042
Spring Crop			
2009 - 10	281	758	2700
2010 - 11	368	1124	3053
2011 - 12	493	1541	3123
2012 - 13	464	1336	2880

Out of total corn production, around 60% is used in poultry feeds, 25% in industries and remaining percentage is used as food for human and as animal fodder.

1.2. Human Food

Maize is a major staple food grain throughout the world, particularly in Africa, Latin America and Asia The maize grains, flour, syrup and oil, all are used as human food. Maize grains contain about 72% starch, 10% protein, 4.8% oil, 5.8 % fiber, 3.0% sugar and 1.7% ash. It is a multi-

CamScanner

purpose crop and is used in different forms. It possesses astonishing nutritional value. Each 100 g of sweet corn grains contain 86 kcal of energy, 6.26 g of sugar, 1.35 g of fat, 3.27 g of proteins and a number of vitamins and minerals. The grains contain considerable quantities of iron and zinc. Maize cooking oil is treated as one of the best oils for human consumption.

Special types of maize such as flint corn, popcorn, sweet corn and flour corn have been developed for classic food uses.

1.3. Animal Feed

It is one of the major ingredients of livestock and poultry feed. About 60% of maize is utilized as poultry feed. It is a standard component of livestock diets where it is used as a source of energy. Many by-products of maize processed for flour and starch such as bran, germs, oil, cobs meal and corn gluten are used in preparation of animal feed. The maize cobs meal is suitable for all kinds of domestic animals and is far cheaper than other meals currently in use. Wanda (an animal feed prepared from maize) carries all required nutritional values including protein and one kg of it can give animals about 4,000 calories.

1.4. Industrial Use

It is a source of raw material for industry, where it is being extensively used for the preparation of corn starch, corn oil, dextrose, corn syrup, corn flakes, cosmetics, wax, alcohol and tanning material for leather industry.

1.5. Bio Fuel

Demand in production of corn is increasing day by day due to its use as bio fuel. Corn grain is rich in starch contents and can be easily converted into ethanol. Since a big infrastructure for planting corn, its harvesting and storing its produce in mass quantities exists all over the world, these factors strongly favor the industry for production of ethanol from maize.

CamScanner

2. AGRO-ECOLOGICAL ADAPTATION AND CLIMATIC REQUIREMENTS

2.1. Agro-ecological Adaptation

The crop is adapted to warm season environments in the low lands of Southern and Central Punjab as well as cold season environments of mid to high altitudes of Northern Punjab. Low land irrigated environments in southern and central Punjab have proven conducive for spring maize crop cultivation during late frost free winters, spring and part of early summers, a long/full growing season having optimum temperature. Similar temperature regime in descending order is again available during late summers attached with early winters in the same agro-ecological zones for a successful autumn crop.

2.2. Temperature

The Maize crop grows well in relatively warm and sunny climate. The optimum temperature for germination is 18-20 °C (not less than 10°C). The seedlings emerge within 5-6 days if proper depth has been maintained. The maize crop is medium to highly sensitive towards climatic conditions e.g. temperature, water stress, water logging etc. Optimum temperature for development at day time is 25-35 °C and in night hours is 17-23 °C.

Maize crop is highly sensitive to extreme temperatures especially frost. In temperature above 35 °C, reduction has been noted in yield levels.

2.3. Photoperiodism

Most of the plants respond specifically to the day length i.e. the number of hours these are subjected to sunlight. Accordingly, the plants are classified as (a) LDP – long-day plants, (b) SDP – short-day plants and (c) DNP – day-neutral plants. The term LDP applies to a crop which shows a response when day length is in excess of a certain length of period and the term SDP applies to a crop which reflects response when day length is below a certain critical length. Compared to the both above, if a crop does not show any response to the day length it is referred as DNP - day-neutral plant. In other words, it does not exhibit any response to photoperiodism. This physiological phenomenon governs suitability of location. for the crops and their optimum period for growth and development.

Maize has been observed as a Day Neutral Plant.

CamScanner

2.4. Optimum Sowing Period

Suitable period of sowing in Punjab has been recommended as under:

Spring crop -------- from 15th January to end February

Kharif crop --------- from 10th July to 10th August.

For Northern areas of Punjab, an addition of about 10 days in the above mentioned dates is recommended. If the cool weather waves hit/persist during sowing period, the benefit of delay in sowing may be accrued for the corresponding interlude. It is, however, advised in this context that the exact sowing time of each variety is always specified by the evolving institution. A new variety should always be sown in the light of given recommendations. The growing period in Punjab ranges between 90-105 days when grown for kernels and 110-120 days when grown for fodder.

CamScanner

3. SOIL CHARACTERISTICS

3.1. Ground Water Depth

The ground water Table should be below two meters. Roots of maize crop can grow up to a depth of more than 6 feet and cannot function well in soils with poor internal drainage.

3.2. Soil Physical Characteristics

Maize crop roots flourish better in soils having good physical properties. It is sensitive to poor internal drainage. The soils having poor structure and lesser infiltration rate are specifically characterized for poor root zone drainage. Such soils should be avoided for maize cultivation.

3.3. Soil Chemical Characteristics

3.3.1. Soil pH

Maize crop prefers soils having less than moderate acidity. Maximum microbial activity for the release of essential nutrients from organic materials occurs at pH 6.0-7.0 and availability of fertilizer nutrients is maintained. The maize crop can grow well between pH of 6.5 - 8 but the optimum pH of soil for maize crop ranges from 6-7.

3.3.2. Soil Nutrients Availability

Maize grows well in soils having sufficient rather liberal amounts of nitrogen, phosphorus and potassium. It demands calcium, magnesium and sulpher in suitable quantities. Maize is also sensitive to deficiencies of certain trace elements particularly zinc and boron.

3.3.3. Soil Salinity

Experiments have revealed that the soil having normal level of salts prove better for maize crop growth. Their level, however, should not be more than 1.7 dS/meter.

CamScanner

4. SEED BED PREPARATION

4.1. Flat Fields

Maize can be sown on flat fields. Precise land leveling of such fields is essential as it facilitates uniform application of water and does not let the crop be subject to over or under irrigation. In addition, it should be ensured that there is no hard layer in the root zone at least up to 40 cm depth. Accordingly, running of chisel plough during seed bed preparation is advisable. In case the hard layer is suspected to be at a level deeper than the range of chisel plough, use of subsoiler is recommended. As the development of roots of maize crop has been observed better in properly pulverized soil, running of rotavator once during seed bed preparation proves highly beneficial. Sowing of maize on flat bed is illustrated in Figure 4.1.



Figure 4.1: Maize sown on Flat Field

4.2. Ridges

Sowing of maize on ridges having one foot width at the base with furrows prepared uniformly has been experienced to be a good method for maize cultivation. The seed is dibbled in this case leaving two thirds of the ridge from the bottom on one side of the ridge. It has been recommended as a result of experiments that preparing the ridges in east-west direction and dibbling the seed on the northern side of the ridge helps the plants grow better on account of better availability of sun shine and the heat during early part of the spring season crop as well as later part of the autumn season crop. The soil should be properly pulverized before making ridges and furrows for uniform absorption of moisture from the water applied in the furrows on one hand and proper proliferation of roots on the other. Sowing of maize on ridges is reflected in figure 4.2.

CamScanner



Figure 4.2: Sowing of Maize on one side of Ridge

4.3. Beds

Sowing of maize on raised beds helps in saving of 20-30 % irrigation water and in accruing higher yield. Moreover, under temporary excess soil moisture or water logging due to heavy rains, the furrows act as drainage channels and crop is saved from negative effects of excessive water. These beds may be irrigated through drip irrigation also by placing the lateral in the centre of the bed. Two rows of crop along the edges of the bed can be successfully irrigated with the help of one lateral. Beds for sowing of maize crop are depicted in Figure 4.3.



Figure 4.3: Beds being irrigated for Sowing of Maize Crop

Sowing of two rows of maize on 1-1.5-foot-wide beds applying water through adjacent furrows on both sides of each bed has proven as a successful method. Proper preparation of soil before elevating beds carries significant weight. Negligence at this stage leaving clods in the soil and not pulverizing the soil may result in poor growth of roots and ultimate reduction in yield.

CamScanner

To have two rows of maize crop on both of the edges of a bed while laying a single lateral in the center of the bed has been observed as an established method of maize cultivation under drip system of irrigation. Following aspect be kept in view while preparation of seed bed which will help in proper irrigation of the beds and final development of maize plants.

i. The soil in the beds should be prepared homogeneously with complete pulverization having no un-rottened plants remnants. This is important for the reason that existence of clods and undecayed plants debris may provide flow routes to the water being emitted from the laterals and the same instead of getting absorbed into the root zone may flow to the furrows. This phenomenon has often proven so much detrimental that it has not only led the entire crop to failure but has brought a bad name to the drip irrigation system also.

ii. The edges of the beds should be raised possibly. Special bed shapers have also been introduced in the market which automatically raise the edges while preparation of the beds.

iii. Development of a minute furrow in the center of the bed accommodating the lateral in it further facilitates proper wetting of the root zone.

CamScanner

5. VARIETIES OF MAIZE

Three types of varieties of maize crop are being cultivated. These are OPVs i.e. open pollinated varieties, hybrid varieties and Bt corn varieties. The Bt varieties do not give any yield potential but are resistant to the attack of insects against which the element of resistance has been introduced genetically. Their brief description is given hereunder.

5.1. Open Pollinated Varieties

The seeds are developed as a result of pollination through wind, insects, birds and other natural mechanisms. Yield potential of OPVs is limited. These can hardly go up to 2500 kg/acre.

5.2. Hybrids

Hybrid seeds are those which develop as a result of controlled pollination where in the pollens come from a known strain or species. The hybrid varieties can reach a yield double of OPVs if the inputs are managed properly.

5.2.1. Single Cross

These are the hybrids which are developed through cross between two inbred lines. These are uniform in height; cobs are of bigger size and give higher yield than both OPVs and double cross varieties.

5.2.2. Double Cross

These are the Hybrids which are developed from the cross between two lines obtained through single cross. Plants of double cross differ in size and cobs are smaller than those of single cross.

5.3. Bt Corn

Bacillus thuringiensis (Bt) is a soil inhabiting bacterium that produces toxins (crystal proteins) which possess insecticidal properties. Genes from this bacterium can be inserted into plants to make them capable of producing insecticidal toxins and convert them into a form resistant to certain insect pests. Bt corn hybrids have successfully proven resistant to the insect pests for which the concerned Bt event was genetically introduced. Accordingly, many different Bt corn hybrids are available in the international market which contain events for both corn borer and corn rootworm.

CamScanner

The important consideration while deciding to go for Bt corn is the economics based comparison between the extra cost of seed to be borne and the loss being borne as a result of attack of the particular insect.

5.4. Varieties Currently Recommended

The varieties recommended currently are given in tabulated form as under:

5.4.1. Spring Varieties

5.4.1.1. Open Pollinated Varieties (OPVs) also referred as Synthetic Varieties

The open pollinated varieties to be sown in spring season are given in Table 5.1 along with the name of institution by whom developed, optimum sowing time and the duration.

Table 5.1: Open pollinated varieties to be sown in spring season

Institution/Company	Sr. No.	Name of Variety	Important Characteristics
Maize and Millets Research Institute, Yusaf Wala, Sahiwal (MMRI)	1	Sahiwal 2002	Sowing Jan 15 to Feb 10, Duration 120 days
	2	Agaiti 2002	Sowing Feb 11 to end Feb, Duration 110 days
	3	MMRI-Yellow	Sowing Jan 25 to Feb 15, Duration125 days
	4	Pearl	Sowing Jan 25 to Feb 15, Duration 125
	5	Malkah 2015	Sowing Feb 15 to Mar 15, Duration 115 days

5.4.1.2. Hybrids

The hybrid varieties to be sown in spring season are given in Table 5.2 along with the name of institution by whom developed, optimum sowing time and the duration.

Table 5.2: Hybrid varieties sown in spring season

Institution/ Company	Sr. No.	Name of Variety	Important Characteristics
MMRI Yusaf Wala	1	FH 810	Sowing Feb 15 to Mar 15, Duration 120 days
	2	Yusaf wala Hybrid	do
	3	YH 1898	do
	4	FH 949	do
Pioneer	1	32B33	Sowing Jan 1 to Mar 15, Single Cross
	2	31P41	do
	3	33M15	do

CamScanner

	4	P1543	do
Monsanto	1	DK6525	Sowing Jan 1 to March 8, Single Cross
	2	DK6103	do
	3	DK9108	do
	4	DK6142	do
ICI	1	Hi Corn 8288 Yellow	Sowing Jan 15 to end Feb, Single Cross
	2	Hi Corn 11 Plus Yellow	Sowing Jan 25 to Mar 15, Double Cross
Syngenta	1	NK 8441	Sowing Jan 15 end Feb, Single Cross
	2	NK 8711	do

5.4.2. Autumn Varieties

5.4.2.1. Open Pollinated Varieties

The open pollinated varieties recommended for sowing in autumn season are given in Table 5.3.

Table 5.3: Open pollinated varieties sown in autumn season

Institution/ Company	Sr. No.	Name of Variety	Important Characteristics
MMRI	1	Sahiwal 2002	Sowing Jul 15 to Aug 10
	2	Agaiti 2002	Sowing Aug 1 to Aug 20
	3	MMRI- Yellow	Sowing Jul 15 to Aug 10
	4	Pearl	do
	5	Malkah 2015	Sowing Jul 15 to Aug 15, Du[illegible]on115 days

5.4.2.2. Hybrids

The hybrid varieties to be sown in autumn season are given in Table 5.4 along with the institution by whom developed, sowing time and the duration.

Table 5.4: Hybrid varieties sown in autumn season

Institution/ Company	Sr. No.	Name of Variety	Important Characteristics
MMRI	1	FH 810	Sowing Jul 15 to Aug 15, Duration 120 days
	2	Yusaf wala Hybrid	do
	3	YH 1898	do
Pioneer	1	30R50	Sowing Jun 15 Aug 15, Single Cross
	2	3025 White	do
	3	30Y87	do
	4	31R88	Sowing Jul 15 to Aug 15, Single Cross
Monsanto	1	DK919	Sowing Jun 20 to Aug 15, Single Cross
	2	DK6714	do
	3	DK6789	Sowing Jul 1 to Aug 15, Single Cross
ICI	1	Hi Corn 984	Sowing Jun 25 to Aug 15, Single Cross
	2	Hi Corn 11 Plus	Sowing Jun 15 to end Aug, Double Cross

CamScanner

	3	Hi Corn 999 Super Yellow	Sowing Jun 25 to Aug 15, Single Cross
	4	Hi Corn 339 Yellow	do
	5	Hi Corn 8081 White	do
Syngenta	1	NK 6621	Sowing Jul 15 to Aug 15, Single Cross
	2	NK 6326	do
	3	NK 6651	do

5.5. Characteristics of Various Varieties

Some general characteristics of few of the varieties given above and certain additional varieties are further jotted down.

5.5.1. Spring Maize Varieties

P1543

1. High Yield Potential
2. Strong stem and roots, lodging resistant
3. Attractive dark reddish yellow grain
4. Crop is ready to harvest in approximately 113 days after seed emergence

P1574

1. Fast early growth and strong stem
2. High Yield Potential and more Grain
3. Attractive dark reddish yellow grain
4. Characterized by staying green till harvest thus plants can be used for fodder
5. Crop is ready to harvest in approximately 115 days after seed emergence

32B33

1. Long cobs and reddish grains
2. Strong root system and resistant to lodging
3. Crop is ready to harvest in approximately 115 days after seed emergence
4. PHD (Proven Highly Digestible) Hybrid, also recommended for Silage

31P41

1. Strong root system and resistant to lodging
2. Long and uniform size cobs
3. Crop is ready to harvest in approximately 118 days after seed emergence
4. PHD (Proven Highly Digestible) Hybrid, also recommended for Silage

CamScanner

33M15

1. Strong root system and resistant to lodging
2. Heat Tolerant
3. Characterized by staying green till harvest thus plants can be used for fodder
4. Crop is ready to harvest in approximately 113 days after seed emergence

5.5.2. Autumn Maize Varieties

30R50

1. High test weight and high yield potential
2. Reddish grain and attract good price in market
3. Medium statured plant with strong root system
4. Crop is ready to harvest in approximately 105-110 days after seed emergence

31R88

1. High shelling percentage
2. Strong stem with strong roots
3. Resistant to lodging
4. Stay green character and plant can be used for fodder
5. Crop is ready to harvest in approximately 100-110 days after seed emergence

30Y87

1. Reddish grain with high test weight and high yield potential
2. Stay green character and plant can be used for fodder
3. Crop is ready to harvest in approximately 110-115 days after seed emergence

3025

1. Medium statured plant with strong roots and stem
2. Heat tolerant
3. Suitable for all corn growing areas
4. Crop is ready to harvest in approximately 100-105 days after seed emergence

CamScanner

6. SEED RATE AND PLANT POPULATION

6.1. Assessment of Seed Rate

The seed rate depends primarily on the objective of the farmer whether he wants to obtain seed or grains or fodder or prepare silage. It is quite important to decide the desired plant population first as the same depends directly upon the seed rate which in turn depends on (a) Variety, (b) Time of sowing, (c) Weight of the grain, (d) Method of sowing (e) Germination percentage, and lastly the (f) Soil productivity status. Some of these factors that play critical role in fixation of the seed rate by a farmer are narrated below.

6.1.1. Germination Percentage

It is strongly advised to run the germination test before sowing and adjust the quantity of seed to be sown per acre. This is especially important when the seed has been purchased from the market to save oneself from not only the extra cost of the seed but also the poor production of the crop from that seed.

6.1.2. Date of Sowing

On becoming late in sowing compared to the optimum/recommended time, an increase in the seed rate corresponding to the number of days of delay has always proven useful.

6.1.3. Varietal Considerations

The optimum seed rate of each variety is always recommended by the researchers. It must be considered in letter and spirit and further adjustment because of other factors should be made accordingly.

6.1.4. Soil Concerns

The soil productivity status especially the light soils having low nutrient level often does not support the desired plant population. In such a situation either the seed rate should be adjusted or the soil should be augmented with appropriate quantities of deficient elements. The productivity and particularly the fertility can now easily be enhanced as per requirement of the crop especially through high efficiency irrigation systems.

6.1.5. Method of Sowing

A general recommendation made by the researchers is to use 12-15 kg/acre of seed for drill sowing and 8-10 kg/acre of seed when being sown through dibbling.

CamScanner

6.2. Thinning

Thinning becomes imperative when plant to plant distance appears too low or all the three or four seeds dibbled in the holes grow well. Optimum time for this operation is about 15 days after emergence. A standard uniform distance between plants is one of the key steps in getting maximum number of healthy plants leading to good yield. In case where sowing has been carried out through dibbling, keeping one healthiest seedling intact, the remaining should be thinned out.

6.3. Optimum Range of Plant Population

6.3.1. Production of Grains

Corn yield is highly correlated with plant population which depends very much on the variety and the soil type. Number of kernels per plant is largely a varietal characteristic but heavier soils having good fertility status and high water holding capacity compared to light sandy soils better support higher populations and thus reflect higher yield potential. Recommended populations range from 20,000 to 25,000 for sandy soils, 25,000 to 30,000 for medium soils, and 30,000 to 35,000 for heavy soils. The seeding rate (as per desired plant population) should positively commensurate with the tested germination percentage of the seed. It also has its correlation with the tillage, hybrid tolerance and stand ability.

It should, however, be always kept in view that extremely high plant populations lead to increased lodging, smaller ears, lower number of kernels per ear and thus lower yields. The effect of too high plant population on yield is reflected through Figure 6.1 given below.

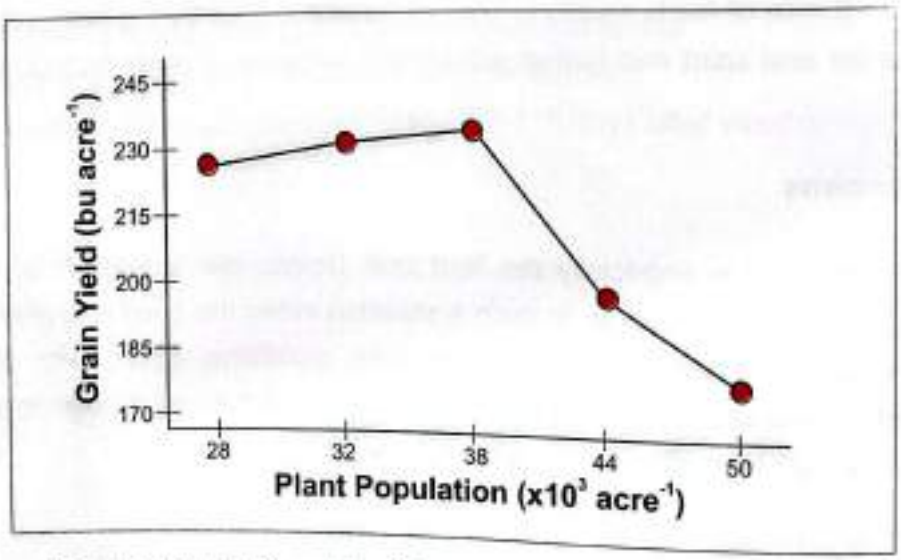


Figure 6.1: Relationship of Grain Yield with Plant Population

The Figure reflects that there was an increase in the yield up to a certain population i.e. 38000 plants per acre but after that there has been noted a sharp decrease in the yield. It is, however,

worth consideration that the gap between 38000 to 44000 plants is quite high. With smaller segmentation, the curve would have shown a gradual decrease.

It has also been reported that in case of early maturing hybrids, the ear size remains smaller than late maturing hybrids. The plant population for early maturing hybrids, therefore, should be kept higher than normal to get maximum yield.

6.3.2. Silage Preparation

The plant population for growing corn for silage should be 3,000 to 5,000 plants higher as compared to planting a hybrid for grains. When grown for silage, plant density maybe increased to as high as 48500 plants per acre. The un-necessary increased plant population may cause competition between maize plants resulting in inhibition of growth and reduction of yield. Usually high-yielding grain corn hybrids produce high biomass yield. There also are corn hybrids developed specifically for silage. The elevated plant population increases the biomass yield and total digestible nutrient production without the risk of lodging due to earlier harvest of corn for silage.

6.3.3. Fodder Production

Sowing for fodder purposes is often made by the farmers by [illegible] spreading of seed. In case the same is planned and arranged in lines, the recommended row to row distance is 40 cm and plant to plant distance is 10 cm. This will provide about 100,000 plants per acre.

CamScanner

7. METHODS OF SOWING

Maize may be sown with the help of Single Row Cotton Drill, Tractor Drill, through Dibbling along ridges/beds and on edges of the beds. All the methods are briefly discussed below.

7.1. Single Row Cotton Drill

In a fairly or precisely leveled flat field, maize may be sown with the help of single row cotton drill in lines 2 - 2.5 ft. apart.

7.2. Tractor Drill

On flat fields as given above, sowing with the help of tractor using tractor drill can also be carried out at desired row to row distance. Irrigation in this method is normally made through surface flooding.

7.3. Ridges and Dibbling

Converting the field into ridges and furrows and sowing maize on one side of the ridge through dibbling has proven to be a good method for maize cultivation. While sowing on ridges, dibble 3-4 seeds on one side of the ridge leaving one third of the ridge from the top giving a space of 15-20 cm from hill to hill as per season and variety. The field is irrigated through furrows.

7.4. Beds and Dibbling

Beds are prepared having 2-2.5 feet width at the top and seeds are dibbled on both sides of the bed in a way similar to the ridge sowing. Irrigation is provided through furrows.

7.5. Beds and Drilling for Drip Irrigation

Beds are prepared having width as per nature of soil to accommodate planting of maize in paired rows to be served with one lateral in the center. As mentioned earlier, the width of the bed at the top should be fixed in such a way that the distance between two rows of maize remains within limits prescribed for various types of soils. For clayey soils, it is recommended to be 50-60 cm, for loamy soils, it is 40-50 cm and for sandy soils, it should be 25-40 cm. The seed should be planted 2-3 cm inside the bed along the edges of the beds.

CamScanner

8. PLANTING GEOMETRIES

Different planting geometries or sowing patterns or planting designs may be practiced under surface and drip systems of irrigation. The key consideration to be kept in view is to ensure fulfillment of requisite/desired plant population keeping optimum spacing between rows and plants. Following patterns may be adopted for the purpose.

8.1. Geometries under Surface Irrigation

Under surface irrigation, normally three planting patterns are adopted. Suitable spacing between rows and plants under each pattern is given below.

8.1.1. Planting on Flat Fields

On fairly or precisely leveled fields, line sowing with the help of single row cotton drill or tractor drill may be carried out. The standard row to row distance of 60-75 cm and plant to plant distance of 15-20 cm is a good planting geometry. This geometry gives 33725-35973 plants per acre.

8.1.2. Planting on Ridges

Sowing of maize on ridges with furrow has gained wide spread popularity among maize growers. The distance between crest to crest will determine the number of rows which may be maintained as 60 – 75 cm. The distance between dibbling points along the ridge (normally 20 cm) will give the number of plants per row.

8.1.3. Planting on Beds

Beds are prepared of 60 – 75 cm width and maize is sown along the sloppy edges of the beds on both sides through dibbling at a distance of 15 – 20 cm. Irrigation of the rows is provided through furrows. Here again the same number of plants per acre may be achieved as above.

8.2. Geometries under Drip Irrigation

Two planting designs may be adopted while sowing maize under drip irrigation system as detailed below.

8.2.1. Single Row with One Lateral

If the infiltration rate of the soil is high, it is advisable that independent lateral be provided to each row of the crop for successful irrigation. Although initial cost of the system installation will be high but to get a successful crop is more important as it may cover the extra cost borne by the farmer. Single row of maize crop being irrigated with one lateral is portrayed in Figure 8.1.

CamScanner



Figure 8.1: Single Row Planting Geometry for Maize Crop under Drip Irrigation (Each row of maize crop being irrigated with independent lateral)

8.2.2. Paired Rows for Drip Irrigation (by reducing the distance between each two rows being served with one lateral)

Under paired rows, two rows of maize crop are served with one drip line in the centre of the bed while bringing the two rows closer enough to be effectively irrigated through horizontal movement of water emitting from the emitters. The distance between two rows of a pair is critically important. In clayey soils, it should range from 50-60 cm, in loam soils, it should range from 40-50 cm and in sandy soils it should be within 25-40 cm. Paired row plantation is illustrated in Figures 8.2 and 8.3.

Paired row planting with 90 cm between the strips and 30 cm between the two rows of each strip is a successful way of planting maize without affecting the recommended plant population. In many cases it has proved superior to the conventional single row planting system. It improves air circulation and light penetration which enhance the photosynthetic efficiency of the plants. It also prevents lodging of plants in case of unusual wind since the strips provide support to the plants.

CamScanner



Figure 8.2: Paired Rows Plantation of Maize (Note the close spacing between two rows being served with one lateral)

The following Table presents three different forms of geometries under paired plantation and corresponding strength/population of plants per acre.

Table 8.1: Number of Plants per Acre Under Paired Rows Plantation at Different Row Spacing

Sr. No.	Recommended Row to Row Distance(m)	No. of Rows in one Acre Width(60 m or 198 ft.)	No. of Pairs in one Acre Width	Plant to Plant Distance	No. of Plants per Row (Length 220 ft. or 66m)	No. of plants per Acre
1	2.25 ft. or 0.675 m	88	44	6 inches or 0.15 m	440	38720
2				7 Inches or 0.175 m	377	33176
3				8 Inches or 0. 20 m	330	29040
4	2.3 ft. or 0.70 m	86	43	0.15 m	440	37840
5				0.175 m	377	32422
6				0.2 m	330	28380
7	2.5 ft. or 0.75 m	80	40	0.15 m	440	35200
8				0.175 m	377	30160
9				0.2 m	330	26400

CamScanner

It may be noted that by converting the rows into pairs, there does not turn out to be any difference in the total number of rows or plants in an acre. The number of rows, the number of laterals and the number of plants, all will remain the same. It is just to bring every two rows closer enough in the form of a pair as per nature of the soil so that the water emitting from the laterals can effectively reach the roots of the plants.



Figure 8.3: Paired rows being irrigated with one lateral (Note the close space/distance between two rows and the wide space/distance between two pairs)

The plant to plant distance is also governed by the season as well as the type of variety. In spring season, plant to plant distance may be reduced because of better sun light for most of the period of growth of the crop. In autumn crop temperature goes considerably low, especially in the later part of growth. It is thus recommended that wider spacing gives better results. Similarly, the leaves orientation of hybrids is more expanding compared to OPVs. Accordingly, higher spacing proves more fruitful in case of hybrids.

CamScanner

9. GROWTH STAGES OF MAIZE

9.1. Significance of Growth Stages

Two types of growth phases have been noticed in plants in general, one the Vegetative Phase and the other Reproductive Phase. In case of Corn, the vegetative phase has been classified into twenty stages i.e. VE as Emergence Stage, then eighteen stages (V1 to V18) on the bases of number of leaves and lastly the VT as Tasseling Stage. A change in varietal characteristics based on genetics may affect this number of vegetative stages on account of attaining a specific number of leaves at its full height. Moreover, the plants facing nutritional deficiency throughout their life and maturing may also exhibit a reduction in total leaves and thus the number of vegetative growth stages. The reproductive phase has been classified into six stages as R1-R6 named as Silking, Blistering, Milking, Dough, Denting and Physiological Maturity stage respectively. These stages bear considerable significance for the reason that some of the same require specific attention with respect to irrigation, fertigation and pest control measures rather some prove critical with respect to implementation of one or two of the said activities.

9.2. Types of Growth Stages

Detail of both types of growth stages vegetative as well as reproductive is given as under.

9.2.1. Vegetative Growth Stages

The vegetative phase of maize plant has been divided into a number of stages as per variety and growing conditions. Normally, these range between 15-20 stages. The first one is VE i.e. Emergence Stage, then 13-18 stages (V1 to V 13-18) on the bases of number of leaves and the last one is VT i.e. Tasseling Stage. The same are described here below along with their significance in Table 9.1.

Pictures of selected stages of vegetative growth are displayed in Figure 9.1

CamScanner

Table 9.1: Vegetative Growth Stages and Corresponding Activities

Stage Symbol	Stage Name	Stage Identification/Description	Corresponding Critical Activity
VE	Emergence	The Stage starts when coleoptile comes out of the soil and persists till fist leaf shows visible collar.	Attack of Termites and Damping off Disease needs to be attended with due vigilance.
V1	One Leaf	Seedling has developed to the point that the collar of the fist leaf has completely established	do
V2	Two Leaves	Seedling has developed to the point that two leaves have become visible with the collars.	do
V3-V6	Three to Six Leaves with full collars	At V3, seminal roots cease growing and rudimentary tassel appears. The stalk elongates.	Flooding specially the water standing in the field is harmful for plants.
V7-V9	7th, 8th , & 9th Leaf with fully developed collar	The number of kernel rows is apparent. Ear shoots start developing from every above ground node except the last 6-8 nodes [illegible] tassel.	Moisture or nutrient deficiency may reduce kernel number and ear size.
V10-V12	10th, 11th, and 12th leaf with full collars.	Tassel [illegible] ent becomes rapid. Every [illegible] develops within 2-3 days. Stalk length enhances as the new nodes develop.	Shortage of nutrients and/or water at this stage may reduce number of kernels and ear size.
V13-V18	13th to 18th and at times 20th leaf development with collar	Development of 13th to 20th leaf depends on hybrid maturity and genetics. In these stages, the number of kernels per row is determined. Silks grow from the upper ears. Tips of the tassels are visible. The brace roots develop to support the plant during reproductive phase.	This the most crucial period of determination of grain yield especially from V15 onward. Accordingly there shouldn't be any deficiency of water or nutrients at this stage. Such set back will significantly reduce number of kernels per row, ear size and grain yield.
VT	Tasselling Stage	This stage begins about 2-3 days before silk emergence. The last branch of the tassel (branched bunch of male flowers) is fully apparent and the plant reaches almost its full height. Shedding of pollens starts and lasts for about one week on plant to plant bases	This stage is important with respect to pollination process. If the ovules are not fertilized, the kernels do not develop on the cobs.

CamScanner

		completing in overall field in about two weeks.	

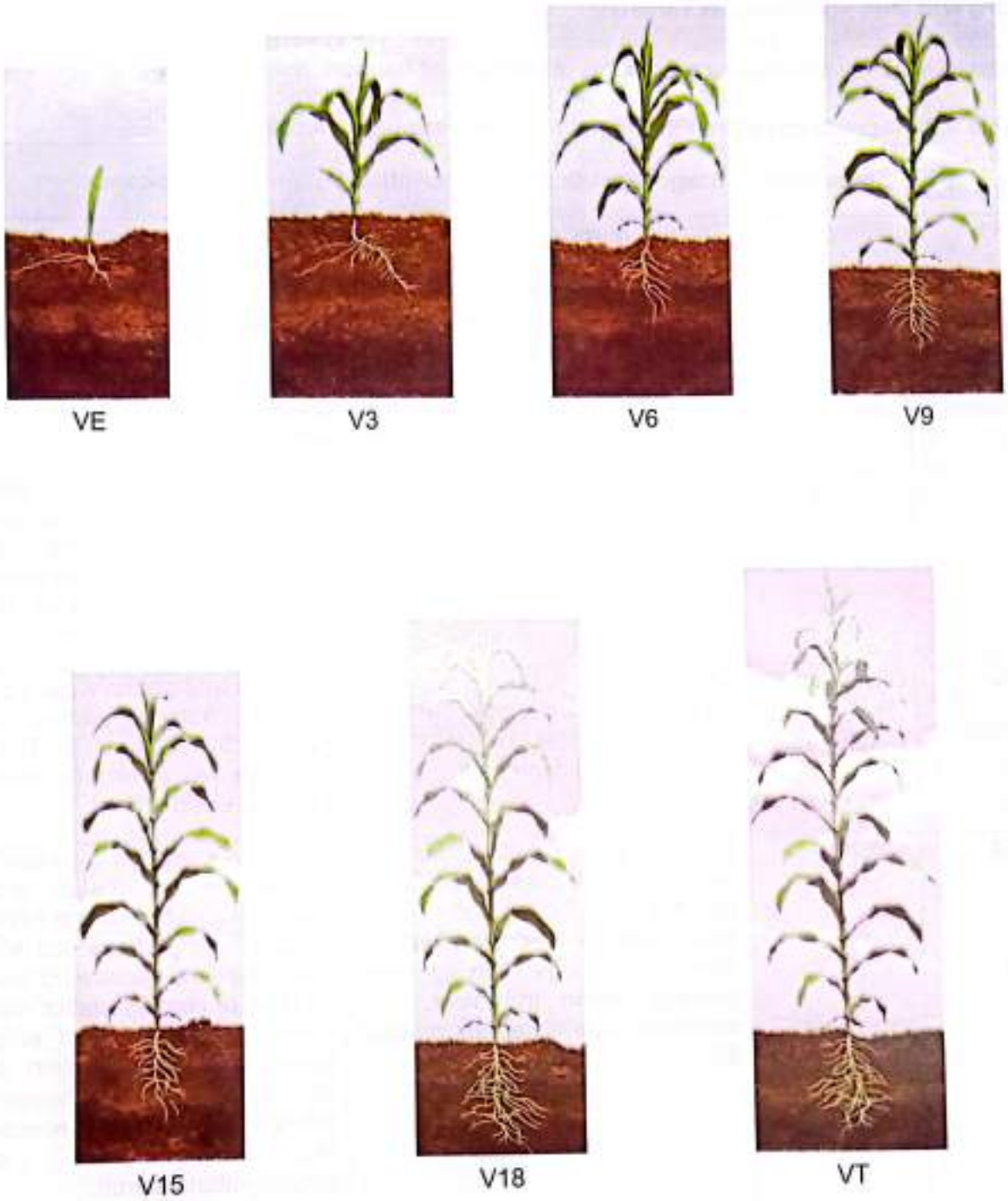


Figure 9.1: Different Vegetative Growth Stages of Maize Plant (VE – VT)

CamScanner

9.2.2. Reproductive Growth Stages

Reproductive phase of maize plant has been divided into six distinct stages naming silking, blistering, milking, dough, denting and physiological maturity. The same are described here under along with their significance in Table 9.2.

Pictures of all the six reproductive stages of maize plant are portrayed in Figure 9.2.

Table 9.2: Reproductive Growth Stages and Corresponding Activities

Stage Symbol	Stage Name	Stage Identification/Description	Significance
R1	Silking	The silk is visible out of the husk. The moist silks catch pollen grains and ovules which get pollinated transform into kernels. The kernels at this stage are white in appearance having little fluid inside.	Pollination completes during this stage. The ovules that do not get pollinated at this stage get degenerated. Any stress at this time specially the water shortage leads to poor pollination thus low seed set and low yield. Uptake of nitrogen and phosphorus is rapid at this stage whereas that of potassium is almost complete. Shortage of nutrients at R1 adversely affects the yield.
R2	Blisteing	The kernels [illegible] white on the outer [illegible] collectively look like a [illegible]. The silks start darkening and drying out.	Nitrogen and phosphorus start shuffling from vegetative to reproductive parts. Their shortage will adversely affect their development.
R3	Milking	This stage is called "Milking" because the kernels when pressed with nails, show milky white starchy secretion inside. The silks begin drying and become brown in colour. The moisture %age of kernels is about 80.	The kernels rapidly accumulate dry matter and gain their size because of filling of starch. Any stress can still affect the yield because of less number of kernels and/or less development in size of each kernel. Heavy infestation of leaves may also adversely affect the grain size because less production of photosynthate/starch.
R4	Dough	Dough means kneaded flour. At this stage, starch accumulation in the endosperm of the kernels	Plant needs to be saved from attack of insects such as stalk

CamScanner

		reaches a consistency level that it appears as dough. The cob becomes light red to pink. The moisture %age in kernels is about 70.	borers and diseases like leaf blights.
R5	Denting	This is the stage when almost all the kernels get dented (have dimples or depressions on the sides) or are under denting phenom-enon. The starch transforms from dough to hard at the outer side but little soft towards the cob side. The moisture %age of kernels at this stage is about 55.	The moisture or nutrient stress at this stage may reduce kernel weight.
R6	Physiological Maturity	At this stage, kernels attain their maximum dry weight. The hard starch layer reaches up to the cob. A blackish abscission layer develops and moves progressively from tip of the ear towards cob. Reaching of this layer to base of majority of the cobs is an indication of complete growth of kernels and the physiological maturity of the plant. The moisture in the kernels at this stage is about 30%.	This is the time to harvest the crop. The ears should be detached from the harvested stalks and dried. The safe moisture %age for storage of grains is 13-15 percent.

CamScanner

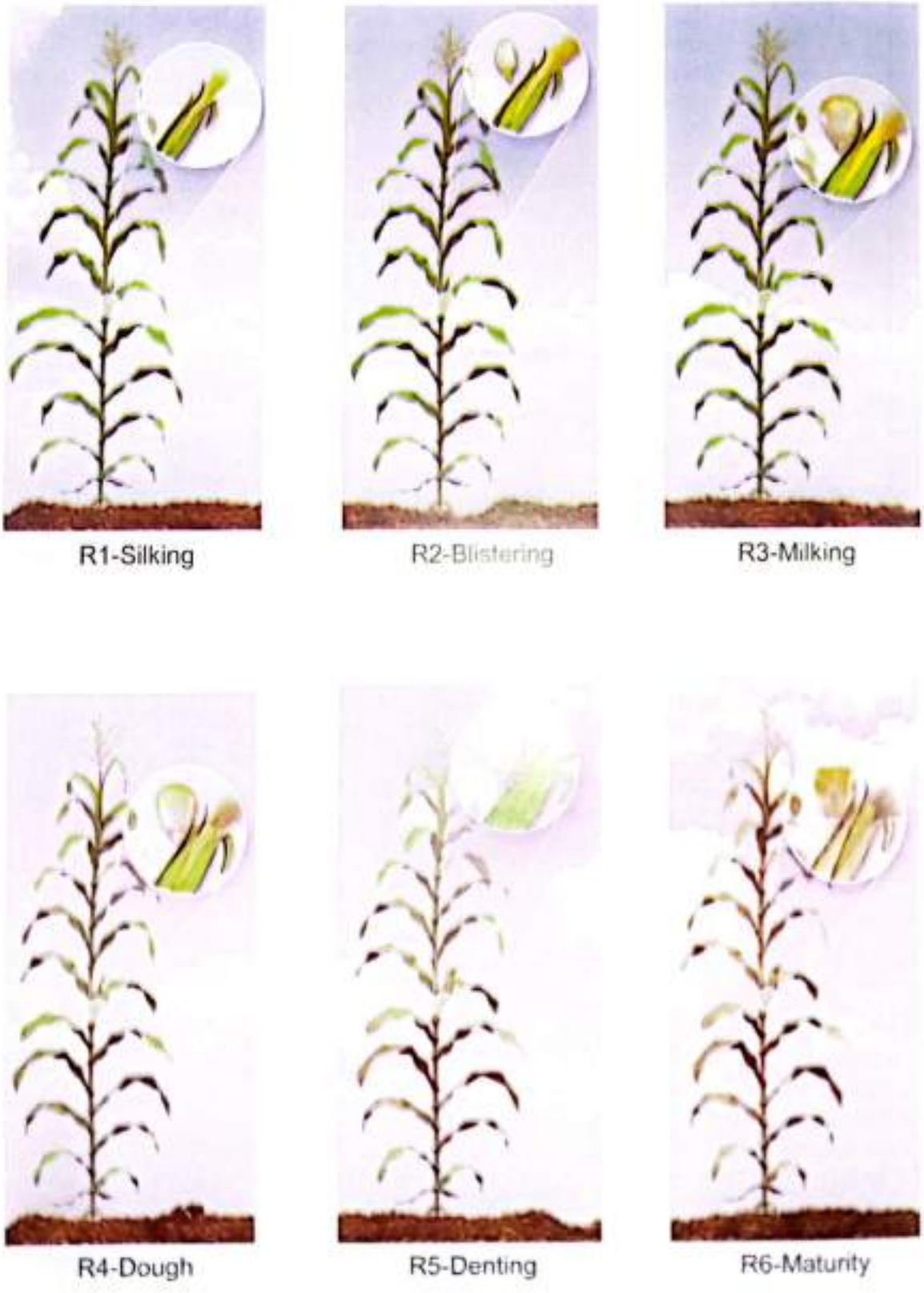


Figure 9.2: Reproductive Growth Stages of Maize Plant (R1-R6)

CamScanner

9.3. Duration of Growth Stages of Maize Crop

University of Nebraska has conducted long term study regarding duration of various growth stages of maize crop. With some variation of nomenclature for certain stages, it has been reported for a crop maturing during 126-140 days that duration of emergence stage ranges from 0-10 days i.e. this stage completes by 10 days, it may take from 11-29 (cumulative) days to complete four leaf stage, 30-46 days to complete eight leaf stage, 47-55 days to complete twelve leaf stage and 56-68 days to complete tasseling stage. On entering into reproductive phase, it completes silking stage within 69-81 days. blistering stage within 82-88 days, milking and dough stages within 89-104 days, denting stage within 105-125 days and the maturity stage gets completed within 126-140 days. For maize varieties of other durations, the days may be adjusted accordingly.

As mentioned above, early maturity stages are critically significant both with respect to irrigation and fertigation. Accordingly, respective care for the said inputs should continue up to the end of that stage as per number of days so that the crop does not face any stress during these days.

CamScanner

10. MAIZE CROP WATER REQUIREMENTS

10.1. General Deliberations

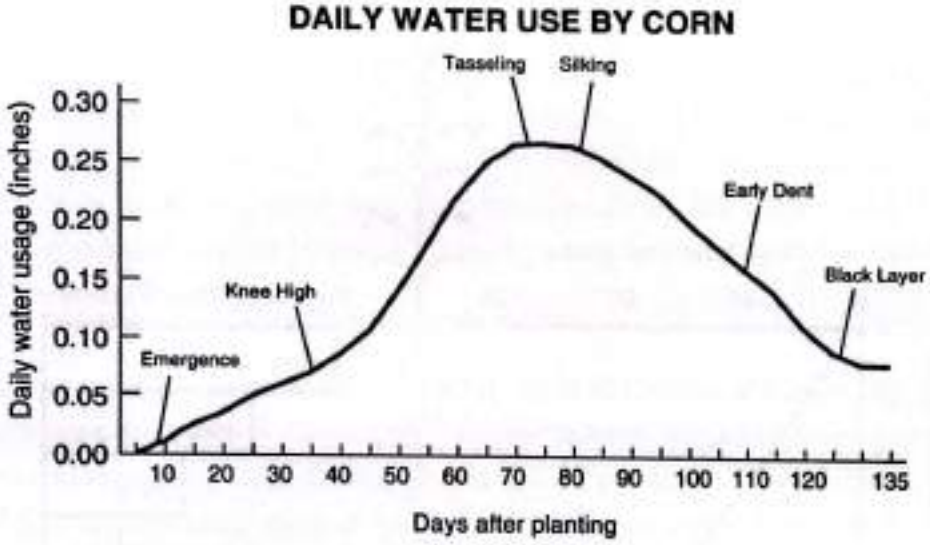
Maize is usually grown as an irrigated crop as it gives potential yields when its water requirements are fulfilled through contrived irrigations. It has also been established that both under irrigation and over irrigation are harmful for the crop. Maize crop can neither bear irrigation stress nor the water standing in the field for a critical duration. Only the required amount should be applied keeping the economics in view. Application of excessive amount of water to corn crop, unlike other crops, leads to reduction in yield both on account of leaching of nutrients and inhibition of aeration in the root zone. The pumping cost comes up as additional loss. Pre-planting irrigation should, however, always be applied to ensure uniform provision of moisture throughout the depth of root zone profile and to bring the seed bed at optimum moisture level for planting.

The crop for its maturity requires about 35 to 45 cm of water. Assuming an average irrigation efficiency of 50% under flood irrigation, production of one acre corn crop would require at least 2.62 (80 cm=2.62 ft.) acre feet of water.

The common drip irrigation design for maize crop is one lateral for two rows (1- 1.5 ft. apart) on beds depending upon the nature of soil. The dripper spacing and the dripper flow rate should also be adjusted as per nature of the soil. Heavier soils demand wider dripper spacing with lower flow rate of the emitters with longer time duration whereas lighter soils need closer dripper spacing with same and higher flow rate of the emitters with shorter time duration.

Getting maximum yield of a crop with minimum consumption of water demands understanding and execution of relevant irrigation management principles. Irrigation Management, also referred as Irrigation Scheduling by some of the experts, is deciding when to irrigate and how much water to apply as per textural and other physical properties of soil, physiological requirements of crop and the atmospheric demand of the moisture in a particular location. Corn crop, too, has its own particular rooting depth, specific daily evapotranspiration demand and definite critical stages of growth where a stress of moisture may significantly reduce the overall yield. Out of the total water used by the crop during a season, about 70-80 % is consumed through evapotranspiration. Although the amount of water consumed by the corn plant from emergence stage to physiological maturity will vary depending upon seasonal fluctuations and different atmospheric demand of each location, the average water use pattern is reflected through the curve shown in Figure 10.1.

CamScanner



Source: Robert Evans, Extension Agricultural Engineering Specialist
D.K. Cassel, Professor of Soil Science. R.E. Sneed, Extension Agricultural Engineering Specialist
Published by: North Carolina Cooperative Extension Service Publication Number AG 452-1

Figure 10.1: Curve showing relationship of maize plant growth and daily water use

The information about stage wise trend and change of water use by corn crop is of critical importance for proper irrigation water management and/or irrigation scheduling of the crop.

The overall depth of irrigation required by the corn crop for maturity has been reported to be ranging from 30 – 45 cm. The difference between the two extremes may certainly be attributed to the variation in varietal and territorial demands. Experiments have revealed that longer season corn hybrids use more water than the shorter season hybrids. In this case, it would be of more significance to determine the water use efficiency in terms of yield per unit of water consumed.

10.2. Rooting Characteristics and Water Uptake Pattern

Under surface irrigation, the roots of corn plant growing in a normal soil, flourish and penetrate up to a depth of 6-8 feet. Its effective root zone under conservative irrigation has been reported to be about 3-4 ft. The water extraction pattern of the corn crop under surface irrigation typically follows the 4-3-2-1 rule i.e. 40% of the water is extracted by the upper 1/4th of the root zone, 30% from the next 1/4th, 20% from the next and 10% from the last 1/4th depth as reflected in Figure 10.2. The extraction of water under drip irrigation will, however, remain confined to the moisture bulb being framed by the emitters as per duration of application.

CamScanner

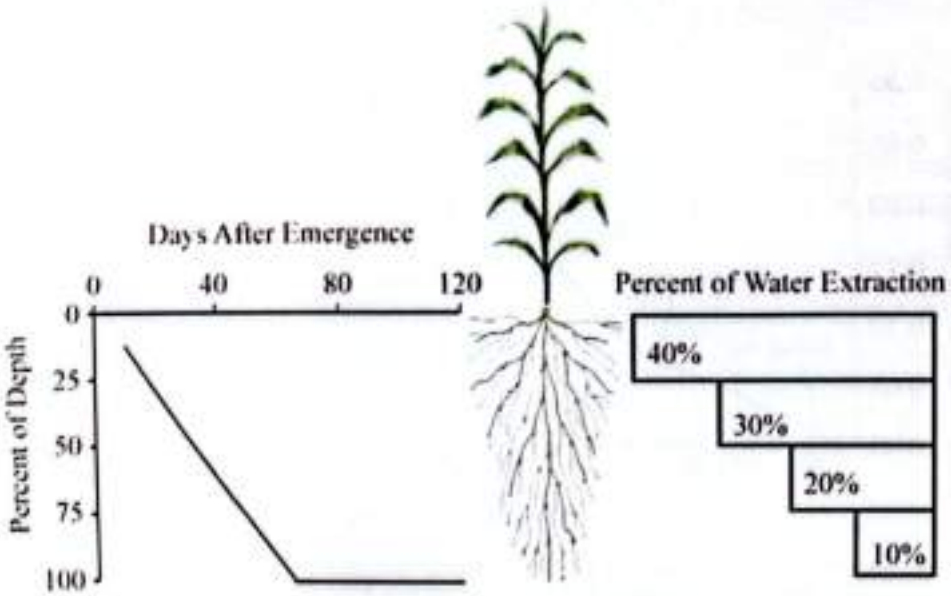


Figure 10.2: Root zone and moisture extraction pattern of Maize plant.

Since the purpose of irrigation is to provide supplemental water to the already stored moisture in the soil, accordingly either estimation of the stored moisture as per textural class of the soil or its compensatory amount based on the atmospheric pull through evapotranspiration becomes important. This will help in fixation of MAD value and related parameters for appropriate irrigation scheduling. Water requirement of corn crop remains high during early reproductive stages. The situation where water is not adequate enough to fulfill the crop requirement, keeping critical stages of the crop in view becomes quite important. *Taselling, silking, blistering, milking and dough stages of corn are critical with respect to irrigation.* Water stress during silking leads to highest reduction in yield. Because of water stress, all the pollens falling on the female silks cannot reach the ovules which in turn do not get fertilized and thus cannot develop into kernels. This is followed by the period when plant transfers the solutes and dry matter to the growing kernels for formation of grains. Accordingly, under stress conditions, pollination, fertilization and grain setting all are adversely affected and thus the yield is reduced on significant levels. After completion of dough stage, water consumption rate of corn plants is reduced because of reduction of actively transpiring leaves area and nearness of the grains to the physiological maturity. This reduction in demand of water by the plants falls down to about 50% by the end of denting stage. This reduction does not exert any harmful effect on the yield. It should, however, remain in view that the corn plants do require certain amount of water till their physiological maturity. Accordingly, light application of water must continue up to harvest. One can stop irrigating corn about ten days before harvest.

CamScanner

10.3. Irrigation Scheduling for Maize

Out of various criteria of Irrigation scheduling referred as (a) Plant based, (b) Soil based and (c) Atmosphere based, the last one has been selected for scheduling irrigations of maize crop grown under drip irrigation systems installed in Punjab. This method has been taken up being the most accurate and easily applicable once the basic considerations are established. The same is recommended for adoption by the farmers of Punjab to schedule irrigations for corn crop.

10.3.1. Values of Reference Daily Evapotranspiration

The values of reference evapotranspiration rates (ET_0) of all districts of Punjab are given in Table 10.1. These values have been developed by International Irrigation Management Institute, Pakistan. The corresponding value for the district can be picked from this Table by a farmer for estimation of daily evapotranspiration of the Corn crop being grown in that area.

10.3.2. Values of Crop Growth Stage Coefficient

To determine the "Crop Factor" referred normally as "K_c" for the day or week or ten days period of irrigation, one should refer to the Crop Growth Stage Coefficient Curve as depicted in Figure 10.3.

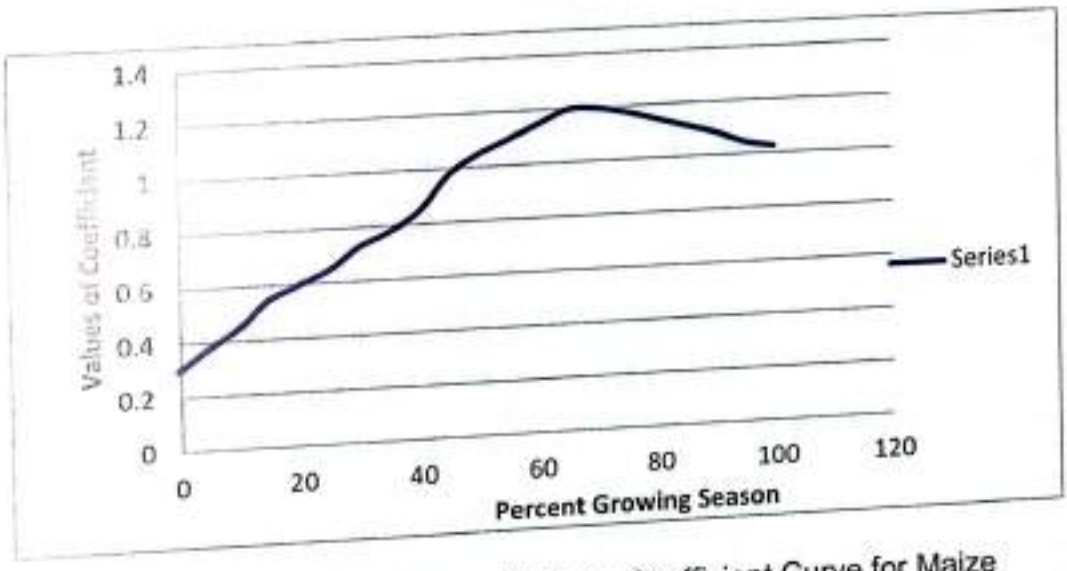


Figure 10.3: Crop Growth Stage Coefficient Curve for Maize

The value as per age of the plants given on "X" axis may be interpolated with values given on "Y" axis and accordingly the factor for a particular day or week or ten days' period may be determined. Through multiplying the reference ET_0 value with this factor, one can easily determine the value of actual evapotranspiration by the crop in that day/week/decade.

CamScanner

In addition to the preparation of coefficient curves, Tables have been developed on the bases of division of the crops growth period according to the four growth stages. These stages have been given the nomenclature as "Initial", "Development", "Middle" and "Late" as indicated in the Table 10.2. The Table includes important agronomic crops, duration of each stage of the crop and the corresponding value of crop coefficient applicable for the respective duration of that stage. It should remain in view that the values of K_c may tend to be on higher side if the crop is healthy, bumper and genetically able to cover higher number of vegetative stages. On the other hand, the coefficient value of a crop having very poor stand, victim of pests and diseases attack and genetically remaining short in stature will be on lower side

Table 10.1: Reference Daily Evapotranspiration Values for All Districts of Punjab

Sr. No	Month wise ETo (mm)/Day												
	Districts	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	Attock	1.3	2.1	3.4	4.7	5.9	6.1	4.8	4.5	4.2	3.0	1.7	1.2
2	Bahawalnagar	1.9	2.9	4.3	6.0	7.6	8.3	6.4	6.1	5.5	4.2	2.6	1.8
3	Bahawalpur	1.8	2.8	4.1	5.5	6.8	7.7	6.2	6.0	5.3	3.9	2.5	1.7
4	Bhakkar	1.5	2.4	3.9	5.2	6.7	7.4	6.1	5.6	5.0	3.5	2.0	1.5
5	Chakwal	1.3	2.1	3.4	4.7	5.9	6.1	4.8	4.5	4.2	3.0	1.7	1.2
6	Chiniot	1.4	2.3	3.6	5.0	6.4	6.8	5.5	5.0	4.7	3.3	1.9	1.4
7	D.G. Khan	1.5	2.5	4.1	5.2	6.4	7.6	6.2	5.9	5.2	3.5	2.0	1.5
8	Faisalabad	1.4	2.2	3.6	4.9	6.2	6.5	5.3	4.8	4.6	3.3	1.9	1.3
9	Gujranwala	1.3	2.1	3.4	4.7	6.0	6.2	5.0	4.6	4.3	3.1	1.8	1.2
10	Gujrat	1.5	2.3	3.7	5.2	6.6	6.9	5.4	4.6	4.8	3.9	2.6	1.7
11	Hafizabad	1.4	2.3	3.6	5.0	6.4	6.8	5.5	5.0	4.7	3.3	1.9	1.4
12	Jhang	1.4	2.3	3.6	5.0	6.4	6.8	5.5	5.0	4.7	3.3	1.9	1.4
13	Jehlum	1.3	2.1	3.4	4.7	5.9	6.1	4.8	4.5	4.2	3.0	1.7	1.2
14	Kasur	1.3	2.1	3.5	4.8	6.0	6.3	4.9	4.6	4.3	3.1	1.8	1.2
15	Khanewal	1.5	2.4	3.9	5.1	6.4	7.1	5.8	5.4	4.9	3.4	1.9	1.4
16	Khushab	1.5	2.4	3.9	5.2	6.7	7.4	6.1	5.6	5.0	3.5	2.0	1.5
17	Lahore	1.3	2.3	3.6	5.3	6.2	6.2	5.4	4.8	4.4	3.2	2.1	1.4
18	Layyah	1.5	2.4	3.9	5.2	6.7	7.4	6.1	5.6	5.0	3.5	2.0	1.5

CamScanner

19	Lodhran	1.5	2.5	4.1	5.2	6.4	7.6	6.2	5.9	5.2	3.5	2.0	1.5
20	M.B. Din	1.5	2.3	3.7	5.2	6.6	6.9	5.4	4.6	4.8	3.9	2.6	1.7
21	Mianwali	1.4	1.9	2.9	4.3	5.7	6.2	5.8	5.1	4.7	3.4	2.1	1.4
22	Multan	1.4	2.1	3.2	4.8	6.1	7.0	6.1	5.9	5.1	3.4	2.1	1.4
23	Muzaffargarh	1.5	2.5	4.1	5.2	6.4	7.6	6.2	5.9	5.2	3.5	2.0	1.5
24	Norowal	1.3	2.1	3.4	4.7	5.9	6.1	4.8	4.5	4.2	3.0	1.7	1.2
25	Nankana Sahib	1.3	2.1	3.4	4.7	6.0	6.2	5.0	4.6	4.3	3.1	1.8	1.2
26	Okara	1.5	2.4	3.9	5.1	6.4	7.1	5.8	5.4	4.9	3.4	1.9	1.4
27	Pakpattan	1.5	2.5	4.1	5.2	6.4	7.6	6.2	5.9	5.2	3.5	2.0	1.5
28	R. Y. Khan	1.9	2.9	4.3	5.7	7.0	7.8	6.4	6.1	5.3	4.0	2.5	1.8
29	Rajanpur	1.5	2.5	4.1	5.2	6.4	7.6	6.2	5.9	5.2	3.5	2.0	1.5
30	Rawalpindi	1.3	2.1	3.4	4.7	5.9	6.1	4.8	4.5	4.2	3.0	1.7	1.2
31	Sahiwal	1.5	2.4	3.9	5.1	6.4	7.1	5.8	5.4	4.9	3.4	1.9	1.4
32	Sargodha	1.5	2.4	3.8	5.3	6.8	7.2	5.8	5.0	4.9	3.8	2.5	1.6
33	Sheikhupura	1.3	2.1	3.4	4.7	6.0	6.2	5.0	4.6	4.3	3.1	1.8	1.2
34	Sialkot	1.3	2.1	3.4	4.7	5.9	6.1	4.8	4.5	4.2	3.0	1.7	1.2
35	[illegible]	1.4	2.2	3.6	4.9	6.2	6.5	5.3	4.8	4.6	3.3	1.9	1.3
36	[illegible]	1.5	2.5	4.1	5.2	6.4	7.6	6.2	5.9	5.2	3.5	2.0	1.5

CamScanner

Table 10.2: Duration of Four Development Stages of Agronomic Crops and Corresponding Kc Values

Sr. No	Crop	Date of Sowing	Duration of Initial stage	Kc initial	Duration of Development stage	Kc Develo-pment	Duration of Middle Stage	Kc Mid stage (Peak Value)	Duration of Late Stage	Kc Late stage	Total days	Date of Harvesting
1	Barley	November	15	0.3	25	0.9	50	1.15	30	1.0	120	April
2	Beans	June	15	0.4	25	0.7	35	1.05	20	0.95	95	Sep & Oct
3	Canola	October	25	0.35	45	0.7	70	1.15	40	1.0	180	Mar & April
4	Castor Beans	March	25	0.35	40	0.8	65	1.15	50	1.1	180	Sep & Oct
5	Cotton	April	30	0.5	50	0.8	60	1.25	55	0.9	195	Nov & Dec
6	Grams	October	20	0.4	30	0.9	45	1.05	20	1	115	Feb & Mar
7	Groundnut	March	25	0.5	35	0.8	45	1.1	25	0.85	130	July & Aug
8	Maize	Feb/July	20	0.5	30	0.85	40	1.2	20/25	0.9	115	May & Nov
9	Millets	June/July	15	0.4	25	0.7	40	1.0	25	0.9	105	October
10	Rapeseed	October	25	0.35	45	0.7	70	1.2	40	1.0	180	Mar & Apr
11	Rice	June/July	30	1.15	30	1.15	60	1.3	30	1.05	150	Nov & Dec
12	Safflower	November	25	0.5	40	0.8	65	1.0	30	0.8	160	April
13	Sesame	June/July	15	0.35	25	1	50	1.1	20	1.0	110	Oct & Nov
14	Sorghum	July	20	0.4	35	0.7	40	1.1	30	0.8	125	Nov & Dec
15	Soybeans	Feb & July	20/20	0.4	25/35	0.8	50/60	1.15	15/20	0.8	110/130	June & Nov
16	Sugarcane	Feb & Sep	30/35	0.5	60/65	1.0	180/ 200	1.25	60/90	0.8	330/390	Dec & Jan
17	Sugar Beets	October	30	0.5	45	0.7	90	1.05	15	0.95	180	April
18	Sunflower	Jan & Feb	25	0.4	35	0.7	45	1.2	25	0.8	130	June
19	Sweet Corn	Feb & July	20	0.3	30	0.7	40	1.15	20	1.1	110	June & Nov
20	Toria	October	25	0.3	45	0.7	70	1.0	40	1.1	180	April
21	Tobacco	October	30	0.4	40	0.8	50	1.2	30	0.9	150	Mar & April
22	Wheat	November	15	0.4	25	0.8	50	1.2	30	0.7	120	April

CamScanner

Maize crop is given at serial no. 8 of the Table. The initial stage of the crop remains for 20 days and the value of crop coefficient for these days is 0.5, the duration of development stage is 30 days and the coefficient value is 0.85, the duration of middle stage is 40 days and the coefficient value is 1.2 whereas the duration of late stage is 20-25 days and the coefficient value is 0.9. These durations are with reference to a crop of 115 days. For varieties having shorter or longer total duration of life, these stage durations may have some plus or minus days. It should, however, be kept in view that shorter the value of days for applying the value of crop coefficient, more efficient is the irrigation schedule. It is just the easiness that is observed in applying a value of coefficient on the basis of these four stages or on monthly basis. Certainly, preparation of irrigation schedule on weekly or decadal bases is better than four stages or monthly bases.

10.4. Sample Irrigation Schedule for Maize Crop

A typical Irrigation Schedule for Maize Crop grown in district Layyah is given in Table10.3.

Table 10.3: Sample Irrigation Schedule for Maize Crop grown in District Layyah

IRRIGATION SCHEDULE FOR MAIZE CROP															
Farmer Name: Farman Ali Basra			District: Layyah			Crop: Maize			Area under Crop: 13.4 Acre			Date of Sowing: 16.7.12			
Date of Harvest: 24.10.12			Q:=24 lps=86 m3/h			Application Rate(mm/hr.):			5.25	No. of Zones: 7		Size of one Zone= 1.91 acre			
Month	Decade No. of month	Decade No. of crop	No. of Crop Days	Corresponding Daily Eto (mm)	Crop Factor (Kc)	Canopy Factor	Daily Basic CWR (mm)	Efficiency Adjustment & Gross CWR	Soil / Rainfall Contribution (mm)	Daily Final CWR (mm)	Application Rate (mm/hr.)	Irrigation Time per zone/Day (hr.)	Irrigation Time per zone/Day (minutes)	Irrigation Time for all zones (hr.)	Volume of Water (m3)
A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
Jul	2	1	5	6.1	0.45	0.3	0.82	0.9	0	0.9	11.3	0.08	5	0.57	245
	3	2	11	6.1	0.64	0.4	1.56	1.7	0	1.7	11.3	0.15	9	1.08	1021
Aug	1	3	10	5.6	0.86	0.4	1.93	2.1	0	2.1	11.3	0.19	11	1.52	1309
	2	4	10	5.6	1.05	0.4	2.35	2.6	0	2.6	11.3	0.23	14	1.86	1598
	3	5	11	5.6	1.2	0.5	3.36	3.7	0	3.7	11.3	0.33	20	2.65	2511
Sep	1	6	10	5	1.2	0.5	3.00	3.3	0	3.3	11.3	0.30	18	2.37	2039
	2	7	10	5	1.2	0.5	3.00	3.3	0	3.3	11.3	0.30	18	2.37	2039
	3	8	10	5	1.1	0.6	3.30	3.7	0	3.7	11.3	0.33	20	2.61	2242
Oct	1	9	10	3.5	1.05	0.7	2.57	2.9	0	2.9	11.3	0.25	15	2.03	1748
	2	10	10	3.5	1	0.7	2.45	2.7	0	2.7	11.3	0.24	15	1.94	1665
	3	11	4	3.5	0.9	0.7	2.21	2.5	0	2.5	11.3	0.22	13	1.74	599
Total															17016

CamScanner

For **hybrid** varieties, however, the CWR is comparatively higher than the normal varieties. It has been observed through experiments that the Kc values of hybrid varieties have proven higher than the Kc values of normal open pollinated varieties of maize. Studies have revealed that the FAO values for open pollinated varieties for initial, development, mid and late stages were 0.4, 0.8, 1.15 and 0.70 whereas the corresponding values for hybrid varieties were 0.38, 0.87, 1.36 and 0.75.

In another experiment, ETa of traditional maize variety V1 was found lower and for hybrid maize variety V4 it was found higher. Seasonal ETa of hybrid maize varieties V2, V3 and V4 were 3, 24 and 34 % higher as compared to traditional variety V1. ETa of V1 varied between 2.7 to 4.8 mm d-1, for V2 between 2.6 to 5.2 mm d-1, for V3 between 3.3 to 6.2 mm d-1 and for V4 between 3.4 to 6.5 mm d-1. The seasonal ETa of selected varieties V1, V2, V3 and V4 was found 411, 422, 512 and 550 mm, respectively. Results showed that ETa of hybrid varieties was higher as compared to traditional varieties. The difference between the values of Eta of the selected maize varieties compared to the traditional variety was found statistically significant ($P \leq 0.05$).

Accordingly, it is recommended that the CWR of hybrid varieties should be increased by about 10 – 20 percent.

10.5. System capacity for Peak Demand

The last aspect to be ensured as a part of irrigation water management for the crop under consideration is to confirm whether the drip system under which the crop is going to be grown is efficient enough to serve and fulfill the water requirements of the crop or not especially at its peak demand. It is not merely enough at all that the system is functioning and the crop has been sown in its command area under a particular geometry. The system must fulfill the crop peak water demand successfully generating an impression with the farm owner or manager that his crop is not going to face any shortage of water at any stage even during the hottest and driest days of the season. The farmer can bear many losses but cannot bear his crop to die before his eyes. Figure 10.4 reflects vigorous maize crop grown through drip irrigation where the system is duly fulfilling the crop water requirement.

CamScanner



Figure 10.4: Corn Crop grown through HEIS duly fulfilling the crop water requirement.

10.6. Water Quality and Maize Crop Response

Maize crop has been observed to be highly sensitive to water quality. It was revealed through research that the grain yield of maize crop was reduced by 10% when electrical conductivity of irrigation water was 1.7 dS/m and it was reduced by 25% when EC of irrigation water was 2.5 dS/m.

CamScanner

11. NUTRITION AND FERTIGATION OF MAIZE

11.1. Nutrients General Requirement

The fertigation requirements depend upon the nutrients already present in the soil and their available quantity is reflected from the soil analysis report. The soils of Punjab show considerable exhaustion in terms of fertility status because of years old high production levels and thus show deficiency of not only the major nutrients i.e. NPK but of certain others as well such as Sulphur and Zink etc. Valuable research revelations have been put forth in this field. Netafim, USA, in their manual on corn production, has presented the percentage of nutrients consumption by different parts of the maize plant and their requirement for an average yield. They have stated therein that the maize crop giving a yield of 240 bushels per acre (6069 Kg/ac, one bushel of corn grains at 15.4% moisture weigh 25.4 kg) would consume 259 lbs. of Nitrogen, 117 lbs. of Phosphorus and 219 lbs. of Potassium. Similarly, definite quantities of remaining eleven nutrients need to be fulfilled for attaining the standard yield of the crop. In another reference again by NETAFIM, consumption rate of various essential elements has been reported for corn (grain + stover) for 150 bushels of yield as reflected in Table 11.1

Table 11.1: Requirement of Nutrients by Corn Crop with 150 bushels (3810 Kg) Yield/Acre

Sr. No.	Name of Element	Quantity in Grains(lbs.)	Quantity in Stover(lbs.)	Total Quantity(lbs.)	Quantity (Kg)
1	Nitrogen	135	68	203	92
2	Phosphorus (P_2O_5)	50	38	88	39.9
3	Potassium (K_2O)	40	155	195	88.4
4	Calcium	13	35	48	21.8
5	Magnesium	10	29	39	17.7
6	Sulphur	11	8	19	8.6
7	Iron	0.1	1.8	1.9	0.86
8	Manganese	0.05	0.25	0.30	0.136
9	Copper	0.02	0.08	0.10	0.045
10	Zinc	0.17	0.17	0.34	0.154
11	Boron	0.04	0.12	0.16	0.073
12	Molybdenum	0.005	0.003	0.008	0.004

CamScanner

Similar information has been developed by the University of Illinois with reference to Mr. Ross Bender for a corn field resulting in 230 bushels of corn grain yield. The same is reflected in Table 11.2. Perusal of the Table 11.2 reveals a pattern of nutrient uptake identical to the above particularly for Nitrogen and Potassium. The Table further indicates that about 2/3 uptake of Nitrogen, Potash, Magnesium, Manganese, Boron and Iron takes place during vegetative growth.

Table 11.2: Nutrient Uptake by Corn Crop for 5842 Kg of Grain Yield/Acre

Nutrient	Unit	Total Nutrient Uptake	Nutrient Removal with Grains	Harvest Index (%)
Nitrogen	lb.	256	148	58
P2O5	lb.	101	80	79
K2O	lb.	180	59	32
S	lb.	23	13	57
Mg	lb.	52	15	29
Zn	oz.	7.1	4.4	62
B	oz.	1.2	0.3	23
Mn	oz.	8.1	1.0	13
Fe	oz.	18.8	3.5	19
Cu	oz.	2.0	0.6	29

Accordingly, if there is a deficiency of any one or more of the essential nutrients, corresponding decrease in the yield will be a natural result. It is, therefore, recommended as a key principle that soil analysis before sowing of the crop should be essentially arranged and the shortfalls of the relevant nutrients should be timely fulfilled. In addition, the crop should be closely watched for any specific symptom if reflected and the deficiency should be removed. The deficiency symptoms of important nutrients in relation to maize along with possible pictures are presented hereunder.

11.2. Nutrients Specific Response

11.2.1. Primary Elements

As already indicated above, Nitrogen, Phosphorus and Potassium are treated as primary elements as these are heavily consumed by the crops and their deficiency drastically affects the yields. Similar is the requirement of maize crop rather its uptake of Potassium is relatively high

CamScanner

compared to many of the other crops. Deficiency symptoms of these elements along with pictures are discussed below.

11.2.1.1. Nitrogen Deficiency Symptoms and Fulfillment

- Light green color or Yellowing of the lower leaves. Yellowing occurs along the midrib. Leaf margins may remain green.
- Premature drying along the midrib and the leaf tips
- Stunted Plants
- Slow flowering of plants
- Poorly filled ears

Illustration of symptoms of nitrogen deficiency is given in Figure 11.1.



Figure 11.1: Symptoms of Nitrogen Deficiency in Maize

Nitrogen is an important element for maize, and the one that most often limits yield. N increases vegetative growth and the photosynthetic capacity of the plant. Nitrogen determines the number of leaves the plants produces and the number of seeds per cob, and therefore determines yield potential. About two-thirds of the N absorbed by the plant ends up in the kernels at maturity.

CamScanner



Figure 11.2: Cardy Meter to Test Cell Sap for NO3 - N

An easy test for Nitrogen Assessment can be conducted with the help of Cardy Meter (Figure 11.2) which reflects the NO_3 – N of the cell sap through measurement of Chlorophyll contents of the leaves. If the test reflects presence of 600-700 ppm of NO_3-N, there is no need of applying Nitrogen to the crop. The test can be conducted at any stage of the crop

11.2.1.2. Phosphorus Deficiency Symptoms and Fulfillment

- Purpling of the tips and margins leaves early in the growing season. The purple or reddish color appears first on older leaves and usually disappears before the plant reaches 18 to 24 inches.
- Poorly developed root system
- Stunted growth of plants
- Less number of kernels having small size

Symptoms of Phosphorus deficiency in maize leaves are depicted in Figure 11.3.



Figure 11.3: Symptoms of Phosphorus Deficiency in young maize plant

CamScanner

Maize is also a demanding crop for P and is quite sensitive to low P availability, especially in the early growth stages. Fertilizer P should be applied at sowing, as most of the P is taken up early in the life of plants, particularly as it is required for healthy root development. For this reason, P fertilizer should be placed where it is available to the roots quickly and the best location for this is banding along the seeding line below the seeds by 1.5-2 inches during sowing of the crop.

11.2.1.3. Potassium Deficiency Symptoms and Fulfillment

- Yellowing or browning of the lower leaves. Yellowing occurs along the edges of the leaf with the midrib remaining green.
- Scorching of the outer leaf edges of young leaves
- Tips of the ears remain unfilled
- Plants tend to lodge

Symptoms of Potassium deficiency are portrayed in Figure 11.4.



(a) (b)

Figure 11.4 (a&b): Symptoms of Potassium Deficiency in Maize

Maize takes up potassium (K) in a relatively large amount during silking. About 86% of K taken up by the plants gets accumulated during silking and only 19% of this K is contained in the ear and stem portion. The most of the K absorbed in the stubbles is recycled through crop residues for subsequent crop production.

A comparison of leaves deficient in Nitrogen, Phosphorus and Potassium with a healthy leaf of maize crop is shown in Figure 11.5, the effects of shortage of Nitrogen and Phosphorus on development of cobs are depicted in Figure 11.6 and the effects of Potassium deficiency in cobs are illustrated in Figure 11.7.

CamScanner



Figure 11.5: Comparison of NPK deficient Leaves of Corn with healthy leaf at the top.

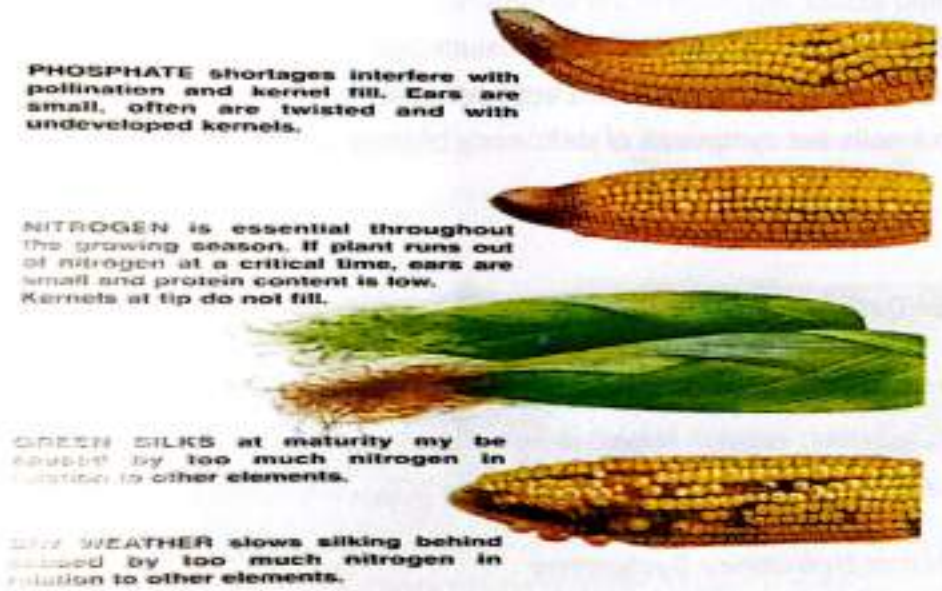


Figure 11.6: Effects of shortage of Phosphorus, shortage of Nitrogen, abundance of Nitrogen and dry weather on silks and kernel development from top to bottom respectively.

CamScanner

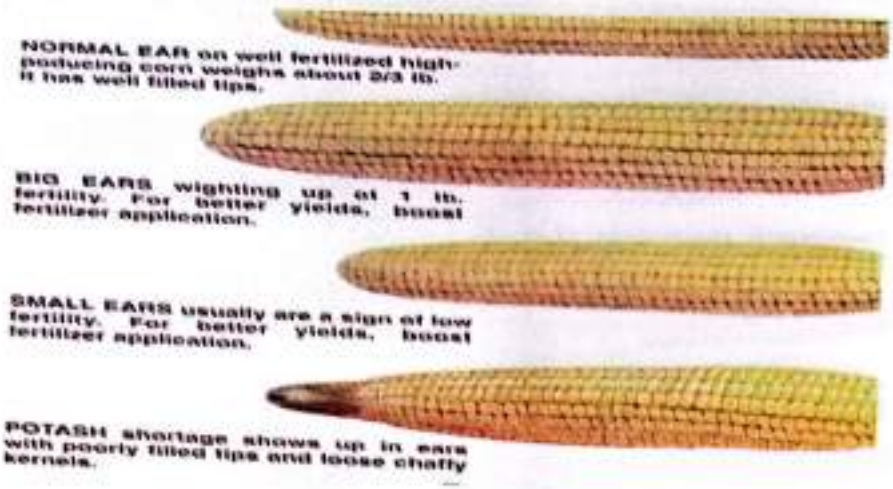


Figure 11.7: Potassium Deficiency Symptoms in Maize Cobs (poorly filled tip at the bottom compared to well filled tips from normal and rich soils)

11.2.2. Secondary Elements

Some of the nutrients such as Calcium, Megnesium and Sulpher are required by the plants in quantities lesser than the major elements. These are referred as secondary nutrients. Calcium is not deficient in our soils but symptoms of deficiency of magnesium and sulpher have been noted in certain fields.

11.2.2.1. Sulphur Deficiency Symptoms

- The entire plant is stunted and pale green in color.
- Yellowing between veins in leaves is sometimes apparent.
- Upper leaves pale green or yellowish in color (Opposite to nitrogen deficiency)

11.2.2.2. Magnesium Deficiency Symptoms

- Longitudinal stripes develop along the midrib of the maize leaf.

These signs are reflected in Figure 11.8.

CamScanner



Figure 11.8: Upper Leaf of Corn reflecting Deficiency Symptoms of Magnesium and Lower Leaf indicating Drought Effects

11.2.3. Tertiary or Trace Elements

There is a third group of nutrients which are required by plants and as such by maize in very small amounts. These are referred to as trace elements or micro nutrients. Maize plant is quite sensitive to the shortage of these elements and shows no Table adverse effects on yield. Effects of their shortage and deficiency symptoms of some of the same are reflected in Figures 11.9 and 11.10. Iron (Fe), Zinc (Zn), boron (B) and molybdenum (Mo) deficiencies have been commonly noted in maize.



Figure 11.9: Iron Deficiency in Maize as Bright Yellow Interveinal chlorosis and Magnesium Deficiency as striping in leaves

CamScanner

Zinc Deficiency Symptoms:

- Light streaking followed by whitish band along the leaf edge
- Midrib and tips remain green
- Short internodes
- New leaves often with whitish edges
- Young stalk shows purplish colour



(a) (b)

Figure 11.10 (a) & (b): Zinc Deficiency Symptoms in Maize

11.3. Nutrients Uptake Curves

Maize plant, like certain others, shows selective uptake of the nutrients during different stages of growth. Keeping the information of this specific pattern of nutrient uptake and ensuring its implementation during fertigation of the crop will help the grower in not only achieving better yield but in reducing the cost of production as well.

11.3. 1. Primary Elements

Uptake Patterns of nitrogen, phosphorus and potassium are discussed below.

CamScanner

11.3.1.1. Nitrogen Uptake

It may be noted that the uptake of Nitrogen continues throughout the maize plant life but it is high during tasseling and silking stages i.e. near end of the vegetative stage through early reproductive stages up to the extent that it reaches a level of more than 3.5 kg per day It has also been reported that as much as 22 kg of nitrogen is accumulated and partitioned into the kernels during grain filling i.e. during blistering, milking and dough stages. In addition, it has been reported by Crop Watch, University of Nebraska that more than 50% of Nitrogen uptake by corn plant is completed before the onset of reproductive phase i.e. initiation of R1 stage as depicted in Figures 11.11 11.12 and 11.13

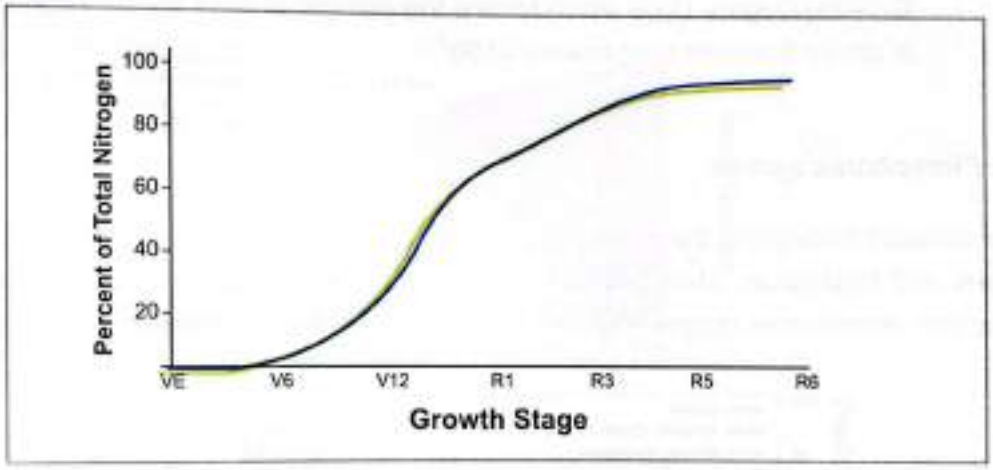


Figure 11.11: Corn plants need increasing levels of nitrogen from the VE to R6 growth

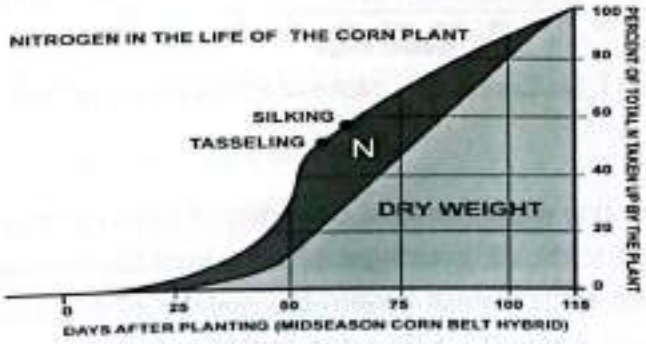


Figure 11.12: Nitrogen Uptake Pattern in maize Plant

CamScanner

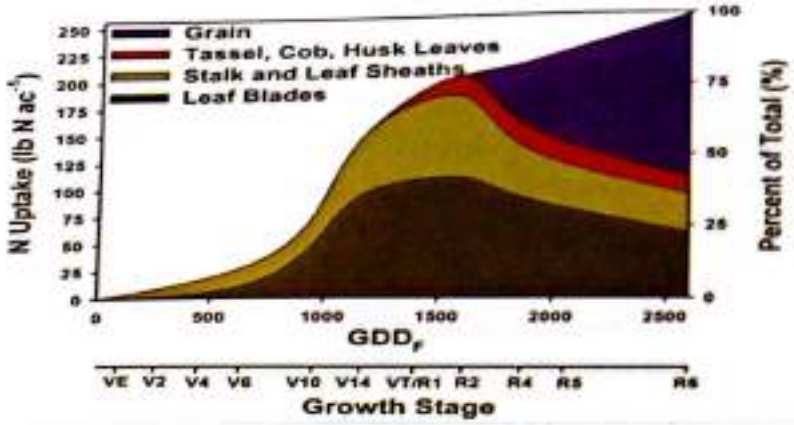


Figure 11.13: Nitrogen uptake during various growth stages of maize plant. GDD reflects Growing Degree Days which means the number of days the average temperature is above the base temperature of 50^0

11.3.1.2. Phosphorus uptake:

It is more constant throughout the season and generally parallels dry weight increases. Contrary to Nitrogen and Potassium, absorption of Phosphorus remains almost equal throughout the vegetative and reproductive stages. Figure 11.14 represents the phosphorus uptake pattern.

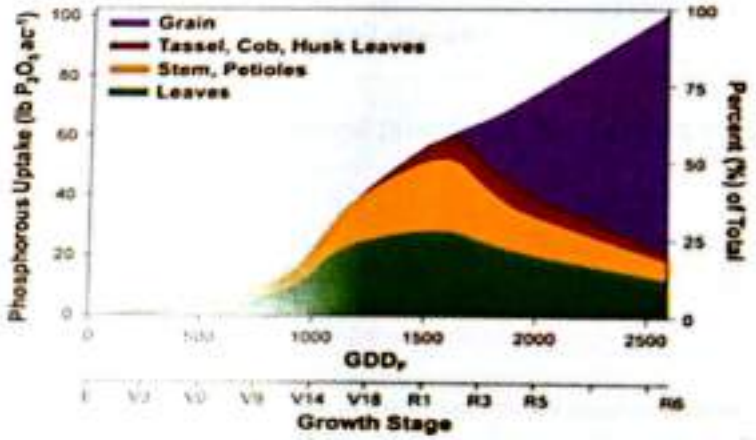


Figure 11.14: Curves for uptake of Phosphorus by corn.

It has also been revealed during experiments at University of Illinois that uptake of phosphorus has been at the peak during V5 to V7, the stages which govern the number of rows of kernels and during V10 to V12, the stages which govern the number of ovules per row. Again, the phosphorus demand is raised during R2 to R6 when final kernel weight is attained by the plant. All these periods are critical in determination of the ultimate yield of the crop. Nitrogen and P

uptake follows the same general trend as plant growth, yet the maximum N uptake occurs during the month prior to tasseling and silking. Significant amounts of N are transferred from leaf tissue to grain during the grain-fill process.

It is further worth consideration that the corn plant requires N and P soon after germination to the maturity for the initiation and completion of growth. Inadequate N availability during the first two to six weeks after planting can result in reduced yield potentials. The majority of N is needed during the period of maximum growth i.e. a month prior to tasseling and silking.

11.3.1.3. Potassium Uptake:

It is similar to Nitrogen and Phosphorus in the initial vegetative stages of maize but is heavily demanded during reproductive stages of the plant as reflected in Figure 11.15.

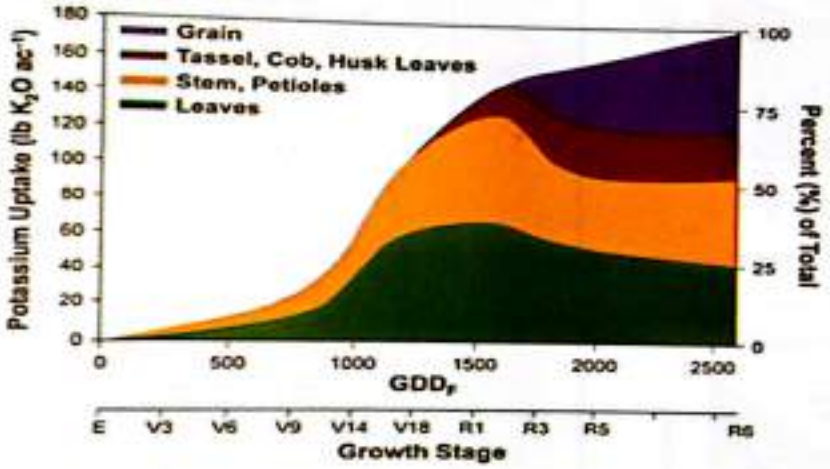


Figure 11.15: Potassium uptake curve for Maize Plant

The assimilation of nitrogen, phosphorus and potassium reaches at a peak during silking and blistering stage. Phosphorus availability is equally critical during the early stages of plant growth and P deficiencies are most often observed during the early part of the growing season. However, P moves very little into the deeper soils, and thus, remains available for longer periods. Potassium accumulates more than three-fourths of total uptake during the time when crop enters the reproductive stage (Silking and blistering).

11.3.2. Uptake of Secondary and Trace Elements

Uptake curves of some of the secondary and minor elements by the maize crop are illustrated in Figure 11.16 with reference to the same source of Bender et al. 2013, Crop Physiology Laboratory Publication, University of Illinois.

CamScanner

It may be noted that the uptake of all the secondary and minor nutrients goes almost parallel to each other during vegetative part and more than 50% of their uptake appears to be completed by the beginning of reproductive stages particularly Magnesium, Manganese, Boron and the Iron. The uptake of iron, however, goes at its peak at the tasseling stage, is lowered by R3 –R4 and again goes up near maturity. Uptake of Sulphur, Zinc and Copper is similar to Phosphorus. These are continuously absorbed throughout the life of maize plant at their respective rates. It is, therefore, recommended that the supply of these elements should be kept constant for the entire season of the crop as there are no fluctuated demands of the same during different stages of the plants.

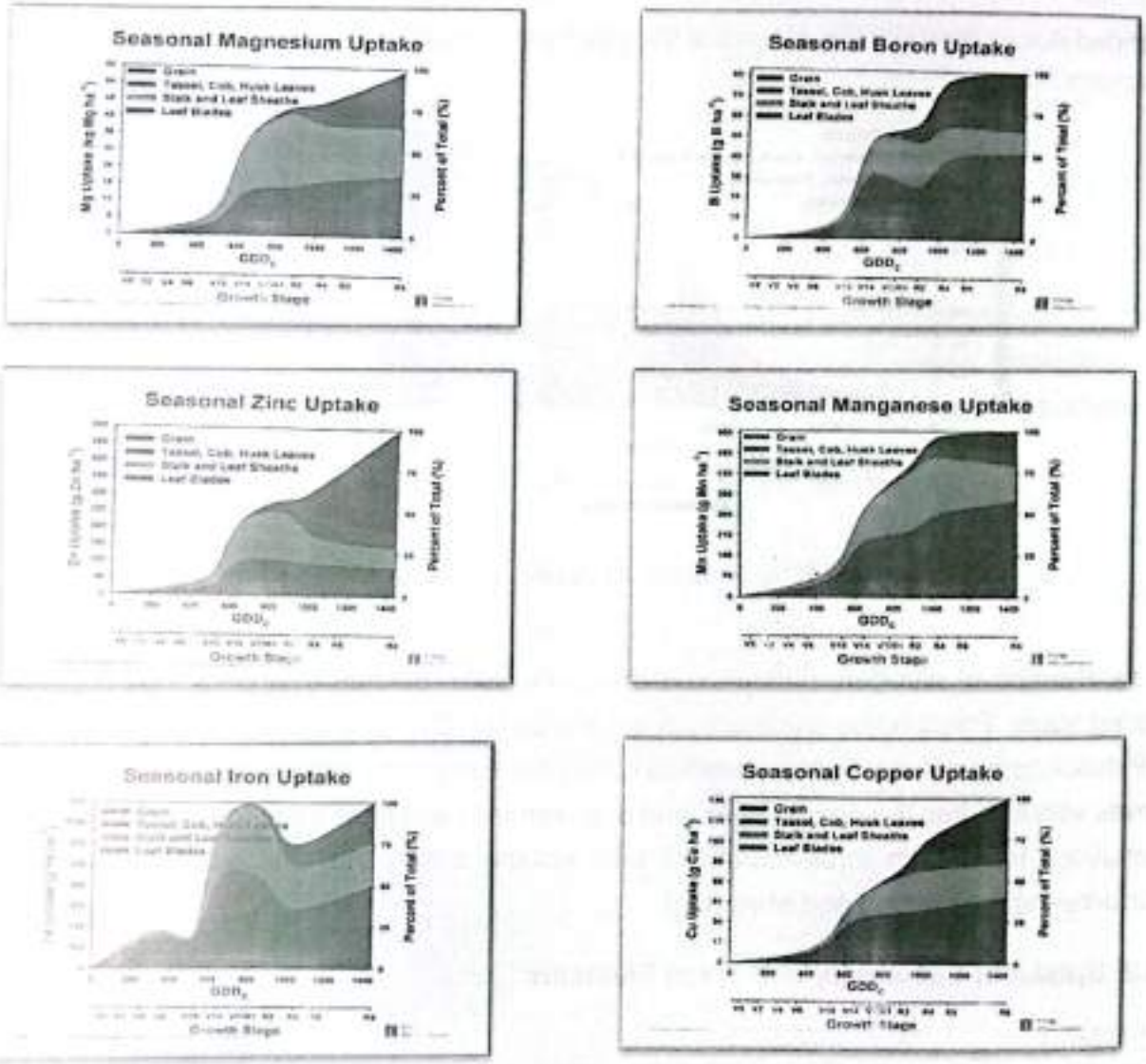


Figure 11.16: Uptake curves of Magnesium, Boron, Zinc, Manganese, Iron and Copper for maize crop.

CamScanner

Under drip irrigation system, application of nutrients through fertigation is the most warranted provision to the plants. Keeping the above given nutrient uptake curves in view and applying the nutrients as per need of the plant at a particular stage is highly promising in getting potential yields.

11.4. Fertigation Schedule for Maize Crop

A sample fertigation schedule for maize crop as per fertility status of medium soils of Punjab has been prepared and is given below as Table 11.3.

The Table has been prepared on excel sheet and its transformation as per soil analysis report of any farm and the uptake curves can be easily made by entering the values in appropriate boxes.

CamScanner

Table 11.3: Sample Fertigation Schedule for Maize Crop

Particulars	N (Kg/Acre)	P_2O_5 (Kg/Acre)	K_2O (Kg/Acre)
Recommendation by Soil Fertility Research Institute	68	46	25
Fertigation Efficiency (Percent)	95	45	80
Nutrient recommendations for optimum yied (kg/acre)	65	21	20
Available in the soil (kg/acre)	0	0	0
Remaining nutrients to be applied (kg/acre)	65	21	20
Basal application (kg/acre)	0	0	0
Remaining quantity of nutrients (kg/acre)	65	21	20
Nutrients for Fertigation (kg/acre)	**65**	**21**	**20**

Physiological Crop Stages

Crop life	Days
Vegetable Phase (1-40 DAG)	40
Flowering Phase (40-60 DAG)	20
Cob Development Phase (60-90 DAG)	30
Grain Development Phase (90-120 DAG)	30
Total	**120**

Ratio and Ratio Days Calculation)

	Ratio				Ratio Days	
Crop life	**N**	**P_2O_5**	**K_2O**	**N**	**P_2O_5**	**K_2O**
Vegetative Phase (1-40 DAG)	**2**	1	1	80	40	40
Flowering Phase (40-60 DAG)	**3**	1	2	60	20	40
Cob Development Phase (60-90 DAG)	**2**	0	4	60	0	120
Grain Development Phase (90-120 DAG)	**1**	0	2	30	0	60
Total	**8**	**2**	**9**	**230**	**60**	**260**

How to Caculate Nutrient (Kg/Acre/Day)?

Nutrient (kg/Acre/Day= Total Quantity of Nutrient for fertigation (Kg/Acre) X Ratio Days of Nutrient in the Stage / Sum of Ratio Days of the Nutrient / No. of Fertigation Days in the Stage

Nutrient (Kg/Acre/Day)

		Nutrients kg/acre/day			Fertilizer kg/acre/day			Fertilizer kg/acre/Season		
Crop life	**Days**	**N**	**P_2O_5**	**K_2O**	**Urea**	**MAP**	**SOP**	**Urea**	**MAP**	**SOP**
Vegetable Phase (1-40 DAG)	40.000	0.562	0.345	0.077	1.074	0.566	0.154	42.945	22.623	6.154
Flowering Phase (40-60 DAG)	20.000	0.843	0.345	0.154	1.684	0.566	0.308	33.684	11.311	6.154
Cob Development Phase (60-90 DAG)	30.000	0.562	0.000	0.308	1.221	0.000	0.615	36.635	0.000	18.462
Grain Development Phase (90-120 DAG)	30.000	0.281	0.000	0.154	0.611	0.000	0.308	18.318	0.000	9.231
Total	**120.000**	**2.247**	**0.690**	**0.692**	**4.590**	**1.131**	**1.385**	**131.582**	**33.934**	**40.000**
					Total fertilizer (kg/acre)			***132***	***34***	***40***
					Number of fertilizer bags / acre			***2.63***	***0.68***	***0.80***
					Nutrients N-P_2O_5-K_2O (kg/acre)			***65***	***21***	***20***

CamScanner

12. WEEDS OF MAIZE CROP AND THEIR CONTROL MEASURES

12.1. Significance

Maize plant is very sensitive to weed competition at early stages of growth. The commonly reported losses due to weeds in maize are greater than 30%. In Pakistan, on an average 45% reduction in maize yield due to weeds infestation has been reported. Uncontrolled weeds may significantly reduce maize yield. Weeds compete with the maize crop for water, nutrients and light. Weeds also create problem during harvesting. Understanding of the ecological relationships in weed-crop competition is, therefore, of significant importance in order to develop an effective crop management technology and to prevent the huge losses due to weeds.

12.2. Weeds Competing with Maize Crop

Since maize is grown in two distinct seasons i.e. spring and autumn, weeds competing with maize crop have accordingly been identified for both the seasons. The lists of weeds for both the seasons are given below:

a) Spring Crop: Bathu, Jangli palak, Jangli cholai, Drank, Dumb ghas, Sengi, Kulfa, Karand, Mako and Maina
b) Autumn Crop: Itsit, Tandla, Cholai, Deela, Sawanki, Kulfa, Khabbal, Lehli, Madhana, Moti Khabbal, Lal dodhak, Mako and Hazardani

The English as well as the technical names of these weeds are given in Table 12.1.

12.3. Technical Names of Weeds and Recognition of their Kind

The weeds have been classified into three general kinds i.e. (1) Weeds of Grass Family, (2) Weeds having Triangular Leaves and (3) Weeds having Broad Leaves. Recognition of a weed as per said classification helps in taking up appropriate control measures especially in selection of proper herbicide.

The kinds, local names, English names, Technical names and their general recognition characters are given in Table 12.1.

Pictures of some of these weeds are shown in Figure 12.1.

CamScanner

Table 12.1: English names, Technical names and general recognition characters of Weeds of Maize

Sr. No.	Kind	Weeds (Common Name)	Weeds (English Name)	Weeds (Technical Name)	General Recognition
1	Grass Family	Deela (Moorak) Khabbal Madhana Dumb ghass Sawank	Purple Nutsedge Bermuda Grass Crow Foot Grass Water grass Jungle rice	Cyperus rotundus Cynodon dactylon Dactyloctenum aegyptiam Polypogon monspelliensis Echinochloa colona	These weeds have pointed leaves and are very hard to be killed. While growing, these weeds spread on the ground.
2	Triangular Leaved	Dhodak Tandla	Sowthistle Digera	Sonchus arvensis Digera arvensis	These weeds have pointed shiny leaves and their margins are tilted upwards. The stem is also triangular.
3	Broad Leaved	Itsit Lehli Karand Bhakhra Hazardani Kulfa Bathu Jangli palak Jangli choli Drank Senji Mako Maina Lal dodhak	Horse purslane Field bindweed Fathen Puncture clover Garden spurge Common Purslane Common goosefoot Broadleaf dock Slender amaranth Prostate knotweed White Sweetclover Black nightshade Burclover Red spurge	Trienthema portulacastrum Convolvulus arvensis Chenopodium murale Tribulus terrestris Euphorbia granulate Potulaca olreacea Chenupodium album Rumex dentatus Amaranthus viridis Polygonum plebejum Melilotus alba Solanum nigrum Medicago polymarpha Euphorbia prostata	The leaves are broad, soft and juicy. Plants have distinct branches and are raised from the ground having erect pattern of growth.

CamScanner



(a) Common Goosefoot at Young Stage



(b) Perennial Sow Thistle



(c) Broad Leaf Dock



(d) Fathen



(e) Bur Clover



(f) Slender Amaranth



(g) Field Bindweed

CamScanner



(h) Purple Nutsedge



(i) Horse Purslane



(j) Common Purslane

Figure 12.1: Pictures of important weeds of Maize Crop (a-j)

12.4. Control Measures for Weeds

Three means/methods/measures are generally practiced for controlling weeds. These are (i) Cultural Measures, (b) Mechanical Measures and (c) Chemical Measures. Normally, one of the three measures proves more appropriate as per growth stage of the crop, nature of the weed, growth stage of the weed and the expenditure involved. A good farmer, however, applies suitable combination of these measure to have effective control on weeds and get maximum return from his crop. All the three measures are discussed below with reference to maize crop.

12.4.1. Cultural Control

To manage a healthy growth of the crop is the best approach to control the weeds. Accordingly, all those steps which help the crop grow better such as use of good quality seed, planting the crop at optimum time, applying proper seed rate, applying recommended dose of fertilizer, line sowing of the crop, applying proper amount of irrigation water at right time will certainly help in controlling the weeds. In addition, letting the weeds grow through special rauni irrigation and then destroying the weeds at their seedling stage through cultural operation before sowing of the maize crop is an effective method of controlling most of the weeds particularly those which compete at

CamScanner

the early stage of crop growth. It is imperative to ensure that the grown weeds do not enter into flowering stage and produce seed for the next season.

12.4.2. Mechanical Control

Two major mechanical methods are adopted to control weeds. One is to bury the weeds in soil through ploughs which invert the soil such as mould board plough. The second is to uproot the weeds in a hot sunny day so that the weeds die then and their dead parts should be collected from the field and destroyed lest these grow again on receiving water especially the weeds having bulbs.

12.4.3. Chemical Control

Two types of herbicides are used for controlling weeds of maize crop; one Pre-emergence and the other Post-emergence as per their time of application. Care should be observed in their proper use. In case, application of herbicides is unavoidable, the types of weeds and the corresponding herbicides are given in Table 12.2.

Table 12.2: Weeds of Maize Crop, Relevant Herbicides and Method of Application

Sr. No.	Name of Weed	Names of Herbicides	Time of Application	Dose per Acre
1	All weeds except Deela and Tandla	Pendimethalin 330E	Before emergence	1.5 lit. In 120 lit. of water
2	Grassy and Broad leaved	Atrazine + Isoxaflutole 550 SC	12-15 days after germination	240 ml in 120 lit. of water
3	Most of the weeds except Bhakhra,	S-metolachlor 960 EC	Within two days of sowing	800 ml
4	Weeds of Grass family and broad leaved	Acetochlor 50 E	Within two days of sowing	500 ml
5	Broad Leaved Weeds	Atrazine + Metolachlor 720 SC	12-15 days after germination	400 ml in 120 lit. of water

CamScanner

13. CROP ROTATION

Rotation of crops is an important principle under management of crops specially to maintain productivity of soils and control of weeds, insects and diseases. Because of having short life duration, maize crop gets easily adjusted in different crop rotation plans. The rotation plans may be prepared on annual or biennial bases. Some plans of both durations are proposed as under.

13.1. Annual Rotation Plans

- Kharif Maize-Wheat
- Potato-Spring maize
- Kharif Maize-Berseem
- Rice-Potato-Spring maize
- Spring Maize-Cotton

13.2. Biennial Rotation Plans

- Kharif Maize-Wheat-Kharif maize-Berseem
- Kharif Maize-Wheat-Cotton-Berseem

CamScanner

14. INSECTS ATTACKING MAIZE CROP

14.1. Significance

The common pests which attack on maize crop are, Termites, Shoot fly, Maize borer, Maize caterpillar, Army worm, Jassids and Aphids. The attack of insect's pests often results in heavy loss to the farmer. Moreover, the cost of pesticides has gone so high that the farmer needs to think times and again before taking up chemical control measures.

14.2. Mode of Damage of Maize Insects and their Chemical Control

The mode of damage rendered by the insects attacking on maize crop and their chemical control measures are given in Table 14.1.

Pictures of important insects attacking maize crop are given in Figures 14.1 to 14.11.

Table 14.1: Mode of Damage rendered by Insects attacking on Maize Crop and their Chemical Control Measures

Sr. No	Common Name with Technical Name	Symptoms and Mode of Damage	Recommended Insecticides
1	Termite *(Ododontotermes obesus)*	Termites eat underground parts of plant. As a result, plant dies. On pulling the plant from soil, it come out easily.	Never use raw farm yard manure.To control the termites through chemical means, apply any compound having Chlorpyrifos. i.e. Lorsban 40 EC (2000) @ 1250 ml/acre or Chlorfenpyr i.e. Steer 10% WDG (2011) @ 800 gm. /acre or Fepronil i.e. Regent 80% WDG (2011) @ 30 gm./acre or Imidacloprid + Fipronil i.e. Lesenta 80% WG (2011) @ 100gm/acre. If the termite incidence is in patches, then apply Fepronil 0.3% G @ 2-3 granules per plant. Clean cultivation (removal of any debris or diseased parts of plants from the field) also delays termite attack.

CamScanner

2	Shoot Fly (*Atherigona varia soccata*)	It attacks more on spring crop and the attack continues for about a month. The larvae enter through top of the plant and start eating the central shoot which gets dried very soon. In addition, the larvae excrete sticky/slimy substance because of which the leaves unite together, the plant growth gets stunted and the cobs remain shorter than normal.	Dip the seed in solution of Imidacloprid i.e. Confidor 60% FS (2009) @ 6 ml per one kg seed. This prevents the crop from attack of shoot fly for about 40 days. On completion of germination, spray Imidacloprid 200 WS @ 200 ml /100 ml of water. or Cypermethrin 10 EC @ 250 ml/acre or Carbosulfon or Advantage 20 EC (2000) @ 250 ml/acre.
3	Maize Borer (*Chilo partellus*)	Chilo partellus, popularly known as stalk borer that occurs during monsoon season is a major pest of Maize Crop. Chilo lays eggs 10-25 days after germination on lower side of the leaves. The larva of the Chilo enters in the whorl and causes damage in the leaves This insect attacks more on the kharif (autumn) crop. The larvae attack from the top making a hole into the shoot. Later on the larvae start eating the leaves and even the young kernels.	Apply Carbofuron 3B @ 6-8 Kg, Fipronil @ 8 Kg, Spray Tracer 24% SC @ 40 ml/100 lit. of water or Hostathion 40 EC @ 600 ml/acre
4	Maize Caterpillar also referred as American Bollworm (*Helicoverpa armigera (heliothis)*)	The larva of this insect is of white colour in the beginning becoming brown later on. Initially the larvae attack on leaves but soon enter into the cobs making holes into the silk and then eating the kernels. After damaging the cobs, the larvae enter into the soil and pupate.	The pupae should be destroyed through hoeing. Apply Chlorpyrifos 40 EC @ 400 ml. Or Ethoprophos i.e. Mocap 5 G @ 20 kg/acre
5	Army Worm *Mythimna separata*	The females lay eggs in cluster form. The young worms attack on the underside of leaves in groups. The larvae eat away the silk and thus kennels cannot develop because of lack of fertilization.	Application of Carbofuron 3B @ 6-8 Kg, Fipronil 0.3% @ 8Kg, Tracer 24% SC @40 ml per 100 lit. water, Hostathion @ 600 ml

CamScanner

6	Jassids *Amrasca devastans* and *Amrasca bigutella bigutella*	Jassids attack on spring maize in April. The young nymphs and the adults suck the cell sap of the leaves. White spots develop on leaves and resultantly the leaves die.	Spray the crop with Ecalux 245 EW @ 1 lit. or Carphos 50 EC @ 500 ml
7	Aphids *Rhopalosiphum maidis*	Aphids attack on the crop just before development of cobs and suck the cell sap. Its attack is more severe on the upper leaves. In addition, a slimy material is excreted by the adults on whom a fungus of black color gets developed leading to inhibition of photosynthesis resulting in reduction of the yield.	Primore 50 DP @ 340 gms



Figure 14.1: Attack of Termites (Odontotermes obesus) on Maize

CamScanner

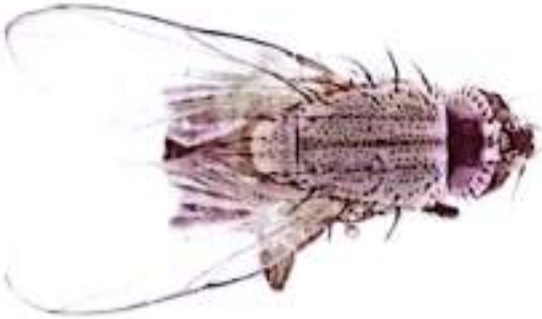


Figure 14.2: Shoot Fly adult

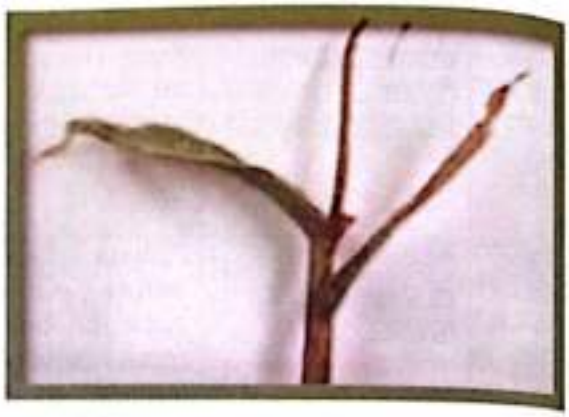


Figure 14.3: Attack of Shoot Fly on Maize Plant



Figure **14.4:** Damage caused by attack of Shoot Fly



(a) (b)

Figure 14.5: (a): Army Worm and (b): Maize Crop after attack of Army Worm

CamScanner



(a)



(b)

Figure 14.6 (a & b): Maize Caterpillar attacking Maize Kernels



Figure 14.7: Damage caused by Maize Stem Borer



(a)



(b)

Figure 14.8 (a) & (b): Attack of Maize Stalk Borer

CamScanner



(a) (b)

Figure 14.9 (a) & (b): Maize Aphids



Figure 14.10: Two types of Jassids *Amrasca devastans* and *Amrasca biqutella biqutella*



(a) (b)

Figure 14.11: (a) Jassid *(Chust tela)* and (b) Aphid *(Sust tela)*

14.3. Integrated Pest Management

A key principle has been given by the experts of this field that *"Complete eradication of a pest is neither necessary nor desirable. Farmers should maintain the presence of harmful pests at low density in a balanced system of natural pests and their enemies."* Accordingly, it is recommendation of the time that principles of "Integrated Pest Management" should be taken up

CamScanner

and use of chemicals should be made only when number of insects crosses the threshold level. Following are the recommended practices to be carried out under integrated pest management.

- Complete control of a pest is not required. Farmers should maintain a natural balance of pests and their enemies.
- Some varieties are specially bred for resistance against certain pests and diseases. The same should be preferred for adoption.
- Growing same crop continuously on the fields facilitates development of hosts for some insects. The crops should, therefore, be rotated.
- The crop residues should be buried to control the growth of insects depending upon the same.
- Weeds often serve as secondary host for a number of insects. The same should be eradicated through all possible means.
- Apply pesticides only when necessary.
- Encourage the living of predators for natural control of insects. The common predators are birds, frogs, ladybirds and spiders.
- The seed should be free from any disease and seed treatment with a suitable chemical must be carried out.

CamScanner

15. DISEASES ATTACKING MAIZE CROP

15.1. Significance

Attack of diseases on a crop may also result in substantial loss to the farm owner. The common diseases which can attack on maize crop in Punjab are Stalk rot, Leaf blight, Cob rot, Stem rot, Maize Smut, Seedling Damping off and Leaf spots. All parts of the plant the ears, leaves, stalks, and roots may be attacked at various stages of development. In many instances diseases result in lower yields, but also reduce the value and quality of the grain and may increase harvesting costs when affected plants lodge.

15.2. Important Diseases and their Chemical Control

Timely recognition of a disease and the extent of its attack is a key parameter for their proper control. Accordingly, the important diseases, their causing agents, symptoms/mode of damage and their control measures are given in Table 15.1.

Symptoms of important diseases and the mode of their damage are illustrated in Figures 15.1 to 15.4.

Table 15.1: Causing agents of Maize Diseases, mode of damage and control measures

Sr. No.	Name of Disease	Causing agent	Symptoms and Mode of Damage	Control Measures
1	Stalk Rot	(i) *Fusarium moniliforme* (ii) *Diplodia maydis* (iii) *Erwinia crysanthamae* (iv) *Macrophomina phaseolina* and (v) *Cephalosporium maydis*	A number of fungi and bacteria are the causal factors. The stalks become weak at the point of attack and fall down. The kernels in the cobs also rot down.	Cultivate resistant and early varieties, dip the seed in fungicide solution before sowing, ensure that Nitrgen is not in quantity higher than required and there is no deficiency of potassium and do not bring corn crop continuously on the same fields.
2	Maize Smut	*Ustilago maydis*	White or brown raised spots develop on the leaves. On maturity, the covering layer of these spots is ruptured and the black spores spread out. The raised spots develop on the cobs as well and the fungus does not let	Same as above

CamScanner

			the kernels attain their normal size.	
3	Leaf Blight	*Helminthosporium madis* and *Drechslera halodes*	Whitish brown spots of longer size develop on the leaves. Lateron these spots get reddish brown leading to decreased photosynthetic activity of the leaves.	Same as above. In addition, spray Deconil W 75 @ 250 gm/100 lit. of water
4	Cob rot	(i) *Diplodia maydis* (ii) *Fusarium* spp. (iii) *Gibberela* spp (iv) *Aspergillus* spp and (v) *Nigro- spora oryzae*	This disease is a result of combination of a number of fungi. The kernels rot in the cobs. During rainy season, the disease intensity increases.	The cobs should be saved from attack of insects through application of suitable insecticides. The remnants of the previous crop should be completely destroyed.
5	Damping off of seedlings	*Fusarium* spp. *Dilodia maydis* *Helminthsporium* spp. and *Pythium* spp. and others	The seedlings die immediately after emergence from the seed. If certain seedlings escape at the initial stage, their height hardly gets about 20-25 cm and the plant dies.	Dip the seed in a solution of one of the following fungicides for at least 20 minutes. a-Vitavax @ 3 gm per 1 kg of seed b-Dividant @ 2 gm per 1 kg of seed.



Figure 15.1 (a&b): Symptoms of Leaf Blight attack on Maize

CamScanner



(a) (b)

Figure 15.2: (a) and (b) Symptoms of Helminthosporium Leaf Spot



(a) (b)

Figure 15.3: Symptoms of Fusarium Stalk Rot on (a) Maize Leaves and (b) Maize Stem



Figure 15.4: Mode of damage of stalk rot caused by Pythium spp.

CamScanner

15.3. Disease Management Principles

There are some disease management principles. If the same are observed carefully, the incidence of diseases can be minimized considerably. These are as under:

- Rotate crops with maize.
- Destroy diseased crop residues.
- Treat seed prior to planting
- Grow resistant varieties.
- Observe proper planting dates.
- Fertilize properly.
- Harvest at proper time.
- Store corn properly.
- Control nematodes with nematicides according to recommendations.
- Use best management practices to minimize other pest problems.

CamScanner

16. HARVESTING, THRESHING AND STORING

16.1. Signs of Maturity and Harvesting

At maturity, when further growth of the maize plant stops almost completely, moisture contents of the kernels fall to about 30%. It is advised that the crop should be left as such for few days till the moisture percentage reaches 20-25. This is indicated in the form of complete drying of the cob sheath.

Another indicator is the development of a black layer at the germ end of the grain which reveals on scratching the surface of the kernel near to the germ. This is the stage when harvesting of the ears should be carried out.

Some varieties have peculiar characteristics that their stems and leaves remain green up to the harvest time. These varieties, termed as "stay green" have a value of being consumed as fodder even after harvest. Their stalks should be stored in a dry place, be protected from sun and rain and fed to the livestock as and when required. Chopping machines are available to chop the stalks into small pieces.

16.2. Threshing Cares

The cobs should then be spread in an open yard under the sun and let these dry till the moisture further falls to a level between 14 to15%. A good indication of this moisture percentage is that the grains start separating from the cobs at their own. The second indication is that the grain cracks if chewed by the teeth. At this stage the cobs are ready for shelling. Two types of shellers, manual as well as tractor driven, are available in the market.

16.3. Storing Cares

Store the cobs in cool, dry and airy atmosphere till shelling arrangement is made or till needed. It should, however, be kept in view that cobs are not stored on earthen floor. Preference should be given to cement floor failing which wooden planks should be arranged. While storing, do not forget to fumigate the store through a suitable fumigant. The ideal moisture percentage for storing the grains is 10-12. At higher moisture percentage, there are more chances of attack of fungi and insects.

CamScanner

17. YIELD

17.1. Significance of Important Parameters

Yield of a crop depends on many parameters such as weather, maize varieties, sowing time, plant population, climatic conditions, irrigation and fertigation etc. An interesting study in this regard has been conducted by a team of researchers of University of Illinois. After long term experimentation, it was deduced that the major parameters determining the yield of maize may be segregated in terms of their value of significance as under.

Table 17.1: Value of factors of maize production segregated in terms of yield and percentage.

Rank	Factor	Value	
		Yield (Bu)	Percentage
1	Weather	70+	27
2	Nitrogen	70	26
3	Hybrid Varieties	50	19
4	Previous Crop	25	10
5	Plant Population	20	8
6	Tillage	15	6
7	Growth Regulators	10	4
Total		**260**	**100**

It cannot be assumed that the study included all the possible factors influencing yield yet it highlights the effect of important inputs in segregated order. It can, indeed, serve as a good guide for an interested farm owner in getting potential yield of maize crop.

The potential yield of an open pollinated variety may touch a level of 85 maunds per acre whereas a good hybrid variety may yield up to 125 maunds per acre in Punjab.

17.2. Indicators of Good Yield

- Color (Lush green)
- Appearance (disease free)
- Plant height (up to 3 m)
- Stem girth (up to 10 cm)

CamScanner

- No. of plant leaves (16-20) Leaf diameter (up to 8 cm)
- Leaf length (up to 1m)
- Root depth (up to 2m)
- Mass & No's of dried grain (up to 1000 grains/cob and 125 g/1000grains)
- Dry biomass above ground (up to 3.5 times of dried grain mass)
- Dry biomass below ground (up to 2 times of dried grain mass)

17.3. Maize Yield Estimation

In some situations, there is a need to estimate the grain yield of corn prior to harvest.

- Count the number of plant rows per acre.
- Count the number of harvestable ears in a row length.
- Count the number of grains of every 5th ear of one row and calculate the average and then weigh the average grains.
- Yield (kgs/A) = (number of crop rows) x (number of ears in selected row) x (average weight per year in kg)

17.4. Potential Yield

The potential yield of an open pollinated variety may touch a level of 3150 kg per acre whereas a good hybrid variety may yield up to 4600 kg per acre in Punjab provided all the inputs are duly fulfilled and nothing proves to be the limiting factor.

CamScanner

LIST OF REFERENCES

1. Bar, I., *Irrigation and Fertigation Recommendations for Corn*. Netafim University, USA.
2. Bayer Crop Science. 2015. *Maize*. Bayer CropScience Pakistan Publcation
3. Bender, R.R. 2013. *Corn nutrient uptake and partitioning*. Department of Crop Sciences, College of Agriculture, University of Illinois, USA.
4. Bender, R.R. 2013. *Drip irrigation and fertigation*. Department of Crop Sciences, College of Agriculture, University of Illinois, USA
5. Bender,R.R., J.W.Haegele, M.L.Ruffo and F.E.Below. 2010. *Modern Corn Hybrids' Nutrient Uptake Patterns*. Crop Physiology Laboratory, University of Illinois, USA.
6. Brown, B., J. Hart, D. Harneck and A. Moore. 2010. *Nutrient Management for Field Corn Silage and Grain in the Inland Pacific Northwest*. A Pacific Northwest Extension Publication, University of Idaho, Oregon State University and Washington State University. PNW 615
7. Bundy, L.G. 2008. *Corn Fertilization*. Cooperative Extension Publishing. A 3340. University of Wisconsin. USA.
8. Davis, J.G. and D.G.Westfall. 2014. *Fertilizing Corn*. Colorado State University Extension Publication No. 0.538.
9. Department of Agriculture and Fisheries, Queensland Government. 2012. *Diseases affecting Maize*.
10. Department of Agriculture and Fisheries, Queensland Government. 2012. *Nutrition, Irrigation and Weeds for Maize*.
11. Directorate of Agricultural Marketing, Department of Agriculture, Punjab. 2008. *Makai ki Paidavar aur Marketing*. Agriculture Marketing Information Service Publication.
12. Fauji Fertilizer Company Limited. *Maize*, Publication of Marketing Group, Lahore.
13. Charles, E.W. and M.A. Shah. 1997. *Irrigation Agronomy, Volume VI, On Farm Water Management Field Manual*. Federal Water Management Cell, Ministry of Food, Agriculture and Livestock, Government of Pakistan, Islamabad.
14. Ferguson, R., 2009. *Using Fertigation for Efficient Nitrogen Application*, Crop Watch, University of Nebraska, Lincoln
15. Grassini, P, H.S. Yang, S. Irmak, J.M. Rees and K.G. Cassman. *Evaluation of Water Productivity and Irrigation Efficiency in Nebraska Corn Production*. Extension Division, University of Nebraska, Lincoln. EC105.
16. Iowa State University. 1996. *How A Corn Plant Develops*. Special Report No. 48.

CamScanner

17. Iqbal, M.S., M. Ashiq and Dr. N. Ahmad. 2004. *Punjab ki Faslon ki Jari Bootian aur unka Insadad*. Ayub Agricultural Research Institute, Faisalabad published by Directorate of Agriculture Information, Department of Agriculture, Punjab, Lahore.
18. Jasinski J, et el. 2008. Sweet Corn – *Pest Identification and Management*. North Central IPM Center, Purdue Extension Publication No. ID 405
19. Khan, M. and N. Haq. 2004. *Weed Control in Maize with Pre and Post- Emergence Herbicides*. Pakistan Journal of Weed Science Research, 10(1-2): 39-46
20. Kluwer, J., *Drip Irrigation in Corn*. Clear Water Supply, University of Idaho Trial in cooperation with Grasslands Dairy, USA
21. Kranz, W.L, S. Irmak, S.J. van Donk, C.D. Yonts and D. L. Martin. *Irrigation Management for Corn*. NebGuide, University of Nebraska, G 1850
22. Department of Agriculture, Punjab. 2015. *Maize Production Plan*. Published by Directorate of Agricultural Information.
23. Nazir, S., 1994. *Crop Production*. National Book Foundation. Islamabad
24. Netafim. *Manual for Corn Production using Subsurface Drip Irrigation*. Netafim, USA
25. Peairs, F.B. 2014. *Managing Corn Pests with BT Corn*. Colorado State University Extension Publication No. 0.708
26. Pioneer. 2011. *Hybrid Corn Production Guide*. Farming Tips & Technologies.
27. Pioneer. *Vegetative Corn Growth Stages and Scouting Tips*, DU PONT.
28. Shapiro, C.A, et ell, 2008. *Fertilizer Suggestions for Corn*. Extension Division, University of Nebraska, Lincoln
29. Wikipedia, the free encyclopedia.2015. *List of maize diseases*. Wikimedia Foundation, Inc.

CamScanner

OFWM



LASER Land Leveling



Watercourse Improvement



Sprinkler Irrigation



Drip Irrigation



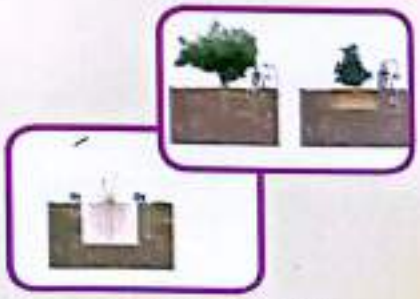
Storage Pond



Solar Coupled HEIS



Training/Human Resource Development



Soil Moisture Meter

Directorate General Agriculture (Water Management)
Punjab, Lahore
Agriculture House, 1st Floor, 21-Davis Road, Lahore
Tel: 042-99200703, 99200713
E-mail: pipipwm@gmail.com, Website: www.ofwm.agripunjab.gov.pk

CamScanner