ISBN: 978-93-88901-00-0

Temperate Maize Cultivation

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Bhumi Publishing

Bhumi Publishing, India

2019

First Edition: 2019

ISBN: 978-93-88901-00-0

Published by:

Bhumi Publishing,

Nigave Khalasa, Kolhapur 416207, Maharashtra, India

Website: www.bhumipublishing.com

E-mail: bhumipublishing@gmail.com

Book Available online at:

www.bhumipublishing.com/books/

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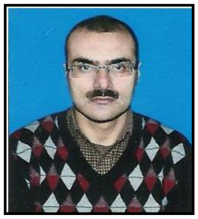

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PREFACE

Agricultural systems are undergoing a rapid transformation and it is in evitable to gear them up for maximum production potential to feed the alarmingly increasing population of the world. Maize is one of the three most important food grain crops in the world, the others being rice and wheat. It is utilized as human food, livestock and poultry feed, raw material for a large number of industries products and as fodder. It is a staple food in 22 countries, two thirds of the produce is consumed as feed, and a very large number (>3500) products/bye-products can be derived from it. In India, maize ranks third with respect to the area under cultivation and production. There has been an impressive growth in maize production and productivity in India. Maize is also major crop of Jammu and Kashmir in terms of acreage under any crop with very diverse cultivation regimes. Maize being staple food of tribal Gujjars and Bakarwals, living in the scattered karewas and hilly areas of state. Moreover, the grains form an important cattle food, being fed to farm cattle and horses. Maize is grown over an area of 3.1 Lakh hectares with productivity of 2.1 tonnes per hectare in the state of Jammu and Kashmir. The average yield level of this crop has also nearly doubled since last decade due to various technological interventions and use of improved cultivars across maize niches of valley. This increase in yield has been mainly attributed to refinement of cultivation practices, use of fertilizers and location specific high yielding composites and hybrids. Maize is gown in the state during kharif season and about 85 % of the cropped area is rainfed. The maize crop as such is prone to the vagaries of rainfall distribution coupled with other biotic and abiotic challenges. Real potential of high yielding varieties can only be harnessed by adopting optimal scientific cultivation practices while raising maize crop.

This book is an attempt to summarize relevance of cultivating maize under temperate climatic conditions and authors have attempted to emphasize on various production principles and addressing various challenges with scientific logic and relevant remedies. The book will prove to be a guiding tool for students, teachers and even entrepreneurs for profitable maize understanding and cultivation under current climatic scenario.

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CHAPTER 1

MAIZE IN JAMMU AND KASHMIR: AN OVERVIEW

Agriculture is the predominant sector in the economy of Jammu and Kashmir. Directly and indirectly, it supports about 80 per cent of the population besides contributing nearly 60 per cent of the state revenue. The total geographical area of the state is nearly 22.2 million hectare and population of 12.5 million, which is approximately 1.04% of the national total. The J&K is divided into three agro-climatic zones: Cold arid desert areas of Ladakh, temperate Kashmir Valley and the humid sub-tropical region of Jammu. Each has its own specific geo-climatic condition which determines the cropping pattern and productivity profile.

In Jammu province, a small portion of the land lies in the plains along the borders of Punjab while the rest of the area is hilly, dominates both in maize and wheat production. About 67 per cent of the area is under maize and wheat production with the production of 21.25q/ha maize and 15.36 q/ha wheat. This region contributes 79.56 per cent and 95.69 per cent of total production of these two cereals respectively. Even though the yield is not high, the region makes appreciable contribution to the cereals production.

The second agro-climatic zone Kashmir is also known as 'cultivator's paradise'. The region practically depends on irrigation, which is easily available. A large area of level land has alluvial soil. Extensive elevated plateaus of the alluvial or lacustrine material (locally called *Karewas*) also exist in the Kashmir valley. These *Karewas* are productive only in the face of sufficient rainfall or adequate irrigation facilities. Rice is the chief crop of this zone, followed by maize, oat, barley and wheat.

Ladakh zone is endowed with bare rocky mountains and bare gravel slopes. Villages are located near pockets of land withlevel ground and irrigation facilities, where cultivation is viable. In this region, barley is the major cereal crop followed by summer wheat. Millets and wheat rank second in importance and are grown in the warmer belt of the region.

Agricultural exports from Jammu and Kashmir include rice, wheat, maize, vegetables, apples, cherries, peaches, pears and saffron. From very long past till date, agriculture of J&K has been maize centric and will remain so for very long, as very large proportion of soil remains rainfed stipulation (85%) leaving very little scope of growing any important crop other than maize. With 34% share of gross cropped area maize is the most predominant crop which alone contributes 35% to the total food grain production. Thus, the goal of achieving self- sufficiency in food grain and also the sustainable growth of agriculture sector depend largely on the growth in maize production; Table 1 illustrates the current area, productivity and production statistics of major crops in Jammu and Kashmir.

Table 1: Crop Production Statistics of J&K (2015-16)

Parameters	Rice	Wheat	Maize	Pulses	Oilseeds
Area (000) Ha	261.1	290.3	15.8	26.7	64.8
Production (000) Tonnes	818.1	462.4	633.2	14.2	51.1
Productivity#	3126	1595	2004	530	789

Maize is the major crop of Jammu a n d Maize production in J&K is increasing year Kashmir in terms of acreage under any crop, by year. The increase in maize nearly one-third of the total cropped area is production in terms of area, output and devoted to its cultivation. It is gown in the state during *kharif* season and about 85 % of the copped area is rainfed. In Jammu & Kashmir maize is grown over an area of 315.8 thousand hectares with production of yield indicate that maize is becoming one of the prominent agro produces in State. Maize is cultivated in almost all districts in State. The leading maize producing districts in State are Kupwara, Baramulla, Budgam and Anantnag. The crop is grown in two seasons 633.2 thousand tones and productivity of– *Kharif* and *rabi*. More than 90 per cent is20.04 qtls per hectare (Anonymous, 2015). Besides, maize is the only alternative to rice grown during *Kharif* season. For the last few years there is a slight decline in the circumstances of low rainfall which production due to less precipitation during are of recurrent occurrence. For the last one decade, the demand for maize grains has also been felt from every nook and corner of the state. Rough maize grain flour (Satoo) and fine grain flour for bread purposes is usually flowering time in the state.

In terms of production and yield, Kupwara stands first among the maize producing districts. The state has also witnessed maximum increase in maize area except Leh and Kargil districts. Taken as breakfast food and in after noon working tea, itt is the staple food of Gujjars and Bakarwals, living in the Kandi and hilly areas. Moreover, the grains form an important cattle food, being fed t o f a r m cattle and horses. The different parts of the plant and the grain are put to a number of industrial uses. The silk threads of maize are

Cropping Pattern:

Oing to variations in climate, soil and nature of irrigation, agricultural operations and the system of cultivation naturally vary from region to region. In the Jammu province, there are usually two crops a year, namely, *Rabi* in winter and *Kharif* in summer. The winter crops, consisting chiefly of wheat and barley, are sown between mid September and mid January, depending upon the moisture in the fields. These are harvested in May-June in the low-lying areas and in July-August at higher altitudes. The summer crops like rice, maize and millet are sown from mid July, according to the geographical location of the place and character of the soil. They are harvested between mid-August and mid-November. As regards the rotation of crops, maize is often followed by wheat or sometimes by toria or barley and mustard, or by some fodder crop. The fodder crops are sometimes sown with cotton, especially on the irrigated lands. Sugarcane fields are frequently left fallow or a fodder crop is succeeded by two fallows and wheat, or by one fallow and cotton, or sugarcane. Cotton is generally preceded and followed by a fallow. Rice is generally grown on the same field year after year in the spring, the land being left fallow or some fodder crop being grown. Wheat is also sometimes grown on rich-manured fields but its output is generally poor. The rotation of crops is, however, often upset by scanty rainfall. In Kashmir province, land usually produces one crop a year; therefore, it is known as *Ekfasli*.

There are, of course, exceptions where farmers produce more than one crop in a year. Ploughing for rice, maize and other autumn crops in the Kashmir province commences in the middle of March. In April and May, seeds of these crops are sown. In June and July, oat, barley and wheat, sown in the previous autumn, are harvested. Maize, rice and other *Kharif* crops are harvested in September and October. In November and December, ploughing for oat, wheat and barley is undertaken. During the October-November, rice and maize as well as other autumn crops are threshed/shelled. In Ladakh, like Kashmir, no customary rotation of crops is followed. However, wheat is not grown on the same land for more than two or three consecutive years, as this process is believed to deteriorate the soil. Wheat is always followed by some pulse. If the soil were much improvised, Pea is sown for a year as it strengthens the soil. The fallow is allowed to restore the exhausted strength of the soil. In some villages, land called Dofasli, gives two crops a year. Trumba, China or kangni give preference to gram. The time of sowing in the frontier districts differs from area to area. Generally, it commences early in the spring. In the low-lying areas, where the *kharif* crop maize follows wheat, the wheat crop is sown anytime from 15 November to 15 January when the soil is not frosty. Maizeis sown in July and August. In J&K, among the food grains, the main crops are rice (29.06 per cent), maize (31.90 per cent) and wheat (23.31 per cent) accounting for 84 per cent of the total cropped area whileas the balance 16 per cent is shared by inferior cereals and pulses. The commercial crops of significance grown in the state are apple and saffron. The consequence of such a cropping pattern is that the bulk of the cultivators have little to spare for buying other necessities of life.

Keeping in view the importance of maize cultivation in the State, a Maize Research Station at Srinagar was started in the year 1958 and was further strengthened with the sanctioning of the Coordinated Maize Improvement Project by ICAR in 1959. This Station called K. D. Farm (Srinagar) functioned as the main centre of Zone-1 which represented the Himalayan Hill region of J & K, U.P, Sikkim, H. P, West Bengal and North-Eastern States. K. D Research station lies between 34.6^0 N and 74.5^0 East at an altitude of 1650 meters. It is about 29 Km away from SKUAST-K main campus at Shalimar and adjacent to Old Airport Srinagar. Maize Research Station has made significant contribution towards achieving a breakthrough in the food production targets of the State. Sher-e Kashmir University of Agriculture Sciences and Technology of Kashmir has a mandate for development of composites and hybrids suitable for low to high altitude conditions of Kashmir alley and development of production and protection technologies for yield gains. Adaption of latest technologies by the farmers improved the production and productivity of maize in Kashmir by three-fold.

Production issues for maize in J&K:

Major constraints for maize cultivation primarily involves predominance of cultivated land races, non-availability of vital inputs, in accessibility, scattered and small land holding and cultivation of maize over a wide range of environmental conditions ranging from approximately 1650 m to above 2,600 m amsl, mostly under rainfed environments. Low productivity levels observed at farmers field is a big challenge for researchers and extension workers to ensure sustainability of maize. Lack of location specific varieties, senile fields, inadequate plant population, moisture stress, (rainfed cultivation) nutrient depletion, poor germination are the major issues at present that have resulted in the decline in production and productivity. The low and highly variable productivity levels are an impediment to investment by resource-poor farmers. Climatic risks like drought and sometimes heavy rainfall and edaphic constraints like poor water and nutrient retention capacity, low soil organic matter (SOM) make maize farming highly vulnerable.

CHAPTER 2

GOOD MANAGEMENT PRACTICES FOR TEMPERATE MAIZE

Maize (*Zea mays*), called corn in some regions of the world, is a grass of tropical origin that has become the major grain crop in the world in terms of total production, with recent production around 967 million tons per year. Most maize grain produced is used as animal feed; in less developed countries it is, however, also a staple food. Maize originated under warm, seasonally dry conditions of Mesoamerica, and was by human selection converted from a low-yielding progenitor species into its modern form, with a large rachis (cob) of the female inflorescence bearing up to 1,000 seeds. Maize is a C4 plant and is very efficient in water use. If subjected to water stress, however, especially during the mid-season pollination process, yields can be much decreased. Crop management needs to be attuned to this moisture sensitivity, and planting date, cultivar and husbandry should be designed to minimize the chance of water shortage in the midseason period. As a grain crop with high yield potential, maize needs an adequate nutrient supply, while the effects of weeds, insects, and diseases, especially during the reproductive period, should be minimized. Tillage is often performed before planting, but maize yields can be as high without tillage as they are with tillage; minimum or no tillage helps to conserve water while maintaining good yields. Planting rates need to be matched to the capability of the soil, and may range from less than 60,000 to more than 100,000 plants per hectare, depending on available soil water and nutrients.

Maize (*Zea mays* L) is the most important and most widely distributed cereal in the world after wheat and rice. It is used for three main purposes: as a staple food crop for human consumption, a feed for livestock, and as raw material for many industrial uses, including bio-fuel production. The name maize is derived from the Arawak-Carib word *mahiz*. It is also known as *Indian corn*.

Globally maize is cultivated over an area of 177 million hectare with a production of 967 million metric tons and productivity of 5.5 million tonnes/hectare (FAO, 2014). The United States of America (USA) is the largest producer of maize contributes nearly 35 per cent of the total production in the world. The USA has the highest productivity (> 9.6t ha^{-1}) which is double than the global average (4.92 t ha^{-1}). In India maize is contributing around 24 per cent of total cereal production (Singh *et al*., 2011). It is cultivated in India over 8.67 million ha with 22.26 million tonnes production having an average productivity of 2566 kg/ha, contributing nearly 8 per cent in the national food basket (DACNET, 2014). Maize is cultivated in all the soil types (except in sandy soil) and being a photo insensitive crop, maize has been adopted in different seasons and in different regions, with crop duration ranging from <90-130 days. Maize is used as human food (23%), poultry feed (51%), animal feed (12%), industrial (starch) products (12%), beverages and seed (1 % each).

In the State Jammu and Kashmir maize area is around 3.1 lakh hectares with the production of 52.7 lakh quintals and productivity is around 1.7 tons per hectare (Anonymous, 2015). It is second most important crop after rice and is a staple food of some tribal areas such as Gujar and Bakarwall (nomadic race). Maize is generally grown under rain fed conditions and on marginal lands particularly in hilly terrains of the Kashmir valley invariably as an intercrop with pulses. It is grown as a sole crop at an altitude range of 1850-2300 m above mean sea level. Lack of location specific varieties, senile fields, inadequate plant population, moisture stress (rain fed cultivation), nutrient depletion, poor germination are the major issues at present that have resulted in the decline in production and productivity in Kashmir.

Optimum plant population, suitable cultivar with adequate amount of precipitation are the important factors for higher productivity, by virtue of which there is efficient utilization of underground resources and also harvesting maximum solar radiation which in turn results in better photosynthesis

Ecology and Growth Requirements:

Temperature and Sunlight :

Maize is a crop of subtropical origin and, though it has been altered by selection for adaptation in different environments, it always responds to higher temperatures. The threshold temperature for seed germination is about 10° C. The crop is relatively sensitive to cool temperatures, and it does not acclimatize to low temperatures as do most cool-season crops. Temperatures of 4° to 6° C may be followed by photo-inhibited physiological damage that may reduce photosynthetic rates for several days thereafter. As a C4 plant, maize responds well to both high temperatures and intense sunlight. Well-watered maize plants reach maximum leaf photosynthesis rates at mid day of 28° to 35° C. Photosynthetic rates of sun-adapted maize do not saturate until light intensity approaches full sunlight. Because photosynthetic capture of sunlight energy is the primary driving force for maize growth and yield, excessive cloudiness and short days tend to lower maize yields.

Precipitation and Water Requirements:

Though maize is water-efficient, the objective to obtain high yields requires a considerable amount of water. Seasonal water use is about 400 to 500 mm in temperate areas. Under rain fed conditions, which is the most common production system, plant water is supplied by seasonal rainfall and stored soil water. Hence, deep soils and those with high organic matter content which store much more plant-available water, are considered the most suitable for maize production. Water uptake gradually increases from the germination into the vegetative growth stage. It reaches a peak by the time the crop canopy is complete, and more in particular from just before until just after the pollination period. Water shortages during this period may prevent successful flowering and fertilization, and thereby greatly reduce grain yield. At full canopy, water use rates may be 6 to 8 mm per day. The seasonal water use by a 10-ton maize crop is typically about 500mm. If good maize yields are to be anticipated this minimum amount of water should be assured.

Weather Stress in Maize Cultivation:

Maize frequently suffers from weather-related problems during the growing season, the effects of which differ with the severity and duration of the stress, and the stage of crop development. Some stress conditions and their impact on crop growth and yield are discussed below.

Flooding:

The major stress caused by flooding is the lack of oxygen needed for the proper function of the root system and the lower stem. Young plants are killed after about 6 or 7 days of being submerged. Death occurs more quickly in hot weather because high temperatures speed up biochemical processes that use oxygen, and warm water has less dissolved oxygen. Cool weather, by contrast, may allow plants to live for more than a week under flooded conditions. Older plants at the six- to eight-leaf stage, can tolerate a week or more of standing water. Total submergence may, however, increase disease incidence and plants may suffer from reduced root growth, even for some days after the water recedes. Tolerance to flooding increases with age, but reduced root function from lack of oxygen is more detrimental to yield before and during pollination than during rapid vegetative growth or during grain fill. Submergence can also coat leaves with soil and reduce photosynthetic activity.

Hail:

The most common damage from hail is loss of leaf area, though stalk breakage and bruising of stalks and ears can be severe as well. Loss charts based on leaf removal studies confirm that defoliation at the time of tasseling causes the greatest yield damage, while loss of leaf area during the first month after planting or when the crop is near maturity generally causes little yield loss. Loss of leaf area in small plants usually delays development, and plants that experience hail damage may not always grow normally afterward.

Cold injury:

Maize is not very tolerant to cold weather. Although death of leaves from frost is the most obvious type of cold injury, other tissues can also be damaged or killed. Loss of leaves from frost is generally not serious when it happens to small plants, but it may delay plant development and postpone pollination. Frost injury symptoms may appear on leaves even when night-time temperatures do not fall below zero degree. If frost kills leaves before physiological maturity in the fall, sugars usually continue to move from the stalk into the ear for some time, yields are generally lower, and harvest moisture may be high due to high grain moisture at the time of frost and slow drying rates that usually follow premature death.

Drought:

Maize is fairly tolerant of dry soils and moisture stress from early vegetative stages until about two weeks before pollination. Mild drought during mid-vegetative stages may even be beneficial because roots generally grow downward more strongly as surface soils are drying up. The crop also benefits from the greater amount of sunlight that accompanies dry weather. During two weeks before, during, and two weeks following pollination, maize is very sensitive to drought, and dry soils during this period can cause serious yield losses. Most of these losses are due to failure of pollination, and the most common cause is the failure of silks to emerge. When this happens, silks do not receive pollen, and, thus, the kernels are not fertilized and do not develop. Developing kernels can also abort for several weeks after pollination. Drought later in grain-fill has a less serious effect on yield, though root function may decrease and kernels may not fill completely. While effects of a prolonged period of drought can never be eliminated in rain fed maize production, there are some techniques that help to reduce the effect of drought on yield. Heavy soils can be drained and tilled to depth in order to improve rooting depth. Reducing tillage, especially on lighter soils, helps to conserve water and make it more available to the crop. Depending on climatic patterns, adjusting planting date can help move the pollination period into a time period of better water supply. Using lower plant densities, and in some cases wider rows, likewise provide more water to individual plants and thereby avoid complete loss of the crop in dry areas. Finally, some modern maize cultivars tolerate or avoid water stress more effectively than others. Efforts are currently underway to identify and incorporate into commercial cultivars for drought resistance. Such hybrids may not be good choices for regions that usually have good growing conditions.

Soil Type:

Maize can be grown on a wide variety of soils, but performs best on well-drained, well-aerated, deep warm loams and silt loams containing adequate organic matter and well supplied with available nutrients. Although it grows on a wide range of soils, it does not yield well on poor sandy soils and heavy clay soils, except with heavy application of fertilizers, deep cultivation and ridging is necessary to improve drainage. In sandy loam soils, good yield could be obtained with increased fertilization and water management.

Maize can be grown successfully on soils with a pH of 5.0 - 7.0 but a moderately acid environment of pH 6.0 - 7.0 is optimum. Outside this pH range results in nutrient deficiency as a result of unavailability of nutrients and mineral toxicity. High yields are obtained from optimum plant population, number of ears and kernels with appropriate soil fertility, and adequate soil moisture. Where possible, it's advisable to have soils routinely analyzed in order to know the characteristics of the soils and to get advice on how to improve soil fertility and/or correct soil pH for optimum maize production. Maize has a relatively deep root system, reaching as much as 2 m deep in some cases, and these roots need space to develop. For normal root development, the maize crop requires a minimum soil depth of 80-100 cm. Any soil shallower than this critical depth will give smaller yields, especially where irrigation is not practiced and where water tends to limit yields.

Site Selection:

Avoid sites with trees, ant hills, shady areas, hard pans, compacted soils, muddy and clayey soils for good yields.

Land Preparation:

Seedbed preparation:

Maize needs to be planted carefully and accurately to achieve the best germination and emergence possible. Seeds will be slow to emerge or fail to germinate if the soil is too wet or dry. The soil should be kept free from weeds by manual weeding or spraying as required.

Conservation tillage:

This method is used by large and medium scale farmers. In this system, maize is grown with minimal cultivation of the soil. The stubble is not completely incorporated and thus contributes to run off control.

Seed quality:

It is important to test the germination and vigor of your planting seed before sowing. The following processes should be undertaken: First look at seed for signs of weathering, disease or physical damage. 2 weeks before sowing, it is advisable to do your own germination test in soil. Seed should be plump and free from visible damage such as broken seed coats.

Planting:

There are three major considerations to be taken into account:

1. When to plant
2. Depth of planting
3. Plant population

When to plant:

As a result of changes in the rainfall pattern, it is recommended to plant the major season in early April through the first week of May after the rains have established good soil moisture. Planting is generally recommended to be done at the onset of rain but since some maize cultivars are drought resistant, dry planting can be done when rain is expected. Delayed planting in relation to the onset of rains will lead to reduced yield especially when there is drought in the critical window of 70 to 100 days after planting when there is tasseling, silk and cob formation. Good soil moisture at sowing time is required before the crop is planted. It is recommended that there should be at least 15 cm of wet soil throughout the soil profile before sowing. Because of this higher water requirement, the majority of corn is planted at places where rainfall is more reliable and there is more of it.

Depth of planting:

Planting and basal fertilizer application is recommended at the same time. The depth of planting should be 5cm deep and fertilizer is 10cm deep or side application respectively. Deep seed placement under dry planting is recommended so that seed germinate only after adequate rains have fallen. However, the depth of planting should be uniform to allow uniform plant growth.

Plant population:

Most of the cultivars are planted at a distance of 60 cm to 70 cm between rows and 20cm between plants giving a plant population of 83,333 and 71,428 plants respectively per ha. The recommended spacing for C15 (Rahmat) is 60 cm between rows and 20 cm between plants when planting one seed per hill. With this planting distances the plant population will be 83.333 plants per hectare. Plant populations that are higher than the optimum will lead to competition among the maize plant resulting into slender plants that will give low yield. Lower plant population will result into low yields (though with bigger cobs) due to reduced number of ears per unit area. Planting should be done in rows, without planting in rows, a farmer will never achieve an optimum plant population. In addition, rows ease field operations like weeding and will facilitate harvesting.

Methods of planting:

Planting can be done either manually or mechanically by the hand.

Manual planting:

Manual planting is the most commonly used method in valley. If properly used, the method can produce excellent results because it gives a proper and uniform plant stand. A measuring tape is used to mark 60/70cm on sticks depending on maize variety along with 20 cm stick for measuring the distances between the seeds. Measured furrow openers are made at a distance of 60cm/70cm between rows depending on maize variety. Seed is placed in furrow openers at required seed to seed distance along with fertilizer on one side at a depth of 10cm. Place the seed and fertilizer and make the final covering. Make sure that the seed and fertilizer are well covered to ensure good contact with moisture. It is important to plant maize seeds at an even depth 5 cm into firm, moist soil to ensure good seed-to-soil contact for moisture uptake and subsequent germination. Plant density and row spacing are critical agronomic factors to get right when sowing maize to maximize yield.

Mechanical planting:

This type of planting has the advantage of being quick, and if well supervised will give excellent results. However, if it is poorly supervised, it will give poor-to-disastrous results. It allows you to plant a large acreage within your pre-determined planting period. Adapt spacing compatible with other mechanical operations like fertilizer application and weeding. Check the machine well before the anticipated planting date to make proper adjustment. Always read the operator's manual and seek advice from the suppliers for effective usage. Every season, make sure that the planter is calibrated to avoid making costly mistakes. Below are some guidelines for calibration:

- Each planter must be tested separately.
- Select plates that will allow the optimum seed placement of seed to go through. Make sure the plate does not allow many seeds at a time.
- Make sure that the driving wheel drops seeds in the furrow opener.
- Count the number of seeds dropped by the planter over a measured length in the field at a set driving speed.

After planting, once the seed absorbs water, germination starts and seedling uses starch reserves in the endosperm to germinate and a root, called the radicle, sprouts from the kernel. At the same time or soon after, a shoot emerges at the other end of the kernel and pushes through the soil surface. This breaking through the soil surface is called emergence. When the tip of the shoot breaks through the soil surface, elongation of the middle section of the shoot, called the mesocotyl, ceases, and the first leaf, which is termed the plumule emerges. The primary roots develop at the depth at which the seed is sown. The first adventitious roots (roots other than those growing from the radicle) start developing from the first node at the mesocotyl, which occurs just below the soil surface. These adventitious roots continue to develop into a thick web of fibrous roots and are the main anchorage for the maize plant; they also facilitate water and nutrient uptake.

Maize vegetation morphology:

In the early growth stages, the leaves and stem are not readily distinguishable. That is because the growing point (whorl) remains underground until the first five leaves have emerged series of enlargements that encircle the stem are called nodes. The space between two nodes is called an internode. The earliest internodes elongate only slightly, so that the space between internodes is only small. However, internodes of older plants elongate much more and account for height in maize. Leaves are made up of a blade which extends from the stem at a node. The stem has two functions: to support the leaves and flowers and to transport water and nutrients. Nutrients are carried in vessels, called xylem and phloem, which are connected to the roots. The xylem transports water and mineral nutrients from the roots and flow one way whiles the phloem flows in both directions and transports organic nutrients in a water based solution. The major function of the leaves is to carry out photosynthesis for grain production.

Seed treatment:

To protect the maize crop from major seed and soil borne diseases and insect pests, treat the seeds before sowing, with any one of the following fungicide viz., mancozeb 75 WP or captan 50 WP or metalaxyl MZ 72 WP along with Imidachlorpid @ 2-4 g / kg seed Mix the chemical thoroughly with the seed. Shake the seed in the container for about 10-15 minutes so that the seed gets thoroughly coated with the chemical.

Seed rate & plant geometry:

For higher productivity and resource use efficiencies optimum plant stand is the key factor. The seed rate varies depending on the purpose, seed size, plant type, sowing methods etc. Following seed rate and plant geometry should be adopted (Table 1).

Table:1 Seed rate and planting geometry for different maize types.

Sr. No.	Purpose	Seed rate (kg/ha) (composite)	Seed rate (kg/ha) (hybrid)	Plant geometry (plant x row, cm)
1	Normal Maize	30	20	60 x 20 70 x 20
2	Sweet Corn	16	10	70 x 20 75 x 20
3	Baby corn	35	30	50 x 20 55 x 20
4	Pop corn	18	14	60 x 20
5	QPM	30	20	70 x 20
6	Fodder	70	60	25 x 10

Note: If due to some practical limitations, farmer is practicing broadcasting method of sowing, enhance seed rate by 10-15 per cent

Nutrient management:

Maize in general and hybrids in particular are very responsive to nutrients applied either through organic or inorganic sources. Application of nutrients depends mainly on soil nutrient status/balance and cropping system. For good yields and higher benefits, the doses of applied nutrients should be matched with the soil supplying capacity and plant demand. However in the absence of soil test following fertilizer schedule may be adopted. Apply compost or well rotten FYM uniformly at the time of first ploughing @ 15 t/ha. This is essential for increasing water holding capacity of the soil.

For irrigated maize:

- For hybrids, 150 kg N, 75 kg P_2O_5, 40 K_2O and 20 kg $ZnSo_4$/ha + seed inoculation with Azotobacter @ 5-10 g/kg seed (if available)
- For composites 120 kg N, 60 kg P_2O_5, 30 K_2O and 15-20 kg $ZnSo_4$/ha + seed inoculation with Azotobacter @ 5-10 g/kg seed (if available).

For rainfed maize:

- For hybrids 90 kg N, 45 kg P_2O_5, 20 K_2O and 10-15 kg $ZnSo_4$/ha.
- For composites 75 kg N, 40 kg P_2O_5, 20 K_2O and 10 kg $ZnSo_4$/ha

Full doses of P, K and Zn and half of N fertilizer may be applied at least 4-5 cm deep into the soil behind the plough (Table:2). Zinc sulphate should be applied only if its deficiency is observed. Then level the land by planking and sow the seeds in lines.

Table 2: Recommended nutrient conversion in amount of available fertilizers

Fertilizers (Kgs)	**Maize under irrigated conditions**				**Maize undr rainfed conditions**			
	Hybrids		**Composites**		**Hybrids**		**Composites**	
As basal application	For one							
	hectare	kanal	hectare	kanal	hectare	kanal	hectare	kanal
Urea	100	5	80	4	60	3	48	2.4
DAP	163	8.15	130	6.5	98	5	87	4.35
MOP	67	3.35	50	2.5	33	1.7	33	1.65
$ZnSO_4$	20	1	20	0.75-1	15	0.75	10	0.5
As top dose in 1st split (urea)	80	4	65	3.25	50	2.5	40	2
As top dose in 2nd split (urea)	80	4	65	3.25	50	2.5	40	2

Under irrigated maize, apply the remaining quantity of nitrogen in two equal splits, each at the time of first weeding and hoeing (about 30DAS), and second dose at the time of second hoeing (about 50 DAS). Fertilizer may be applied 5-7 cm away from the plants and earthing up carried out immediately.

In case of dryland conditions, apply the remaining quantity of nitrogen in a single split at the time of second hoeing and weeding. But it should be kept in mind that this dose might be applied only when there is likelihood of rains and thereafter earthing up should be carried out.

Weed control:

Weeds compete with the maize plant for water, nutrients, space and light. The early stage of a maize plant (first five weeks) is very sensitive to weed competition. Weeds should be controlled and minimized for the first 10 weeks to maximize final yield. Some weeds become alternative hosts of pests and diseases. They reduce profits by lowering the quality, quantity, yields and value of maize. Inefficient weed control is one of the main causes of low maize yields in Valley. Some weeds are parasitic and poisonous to maize. A thick growth of weeds in maize makes harvesting difficult.

After planting the maize, usually weeds will germinate from their seed faster than the rate at which maize will be germinating. They will definitely interfere in the growth of the crop during the critical period of the first five weeks and produce numerous tiny seeds. The seeds are normally dispersed by wind, water, livestock, man, farm machinery and contaminated crop seeds. Once shed, the seeds can stay viable in the soil for up to 20 years. The seeds normally germinate only in response to chemical stimulants exuded by the host roots. Once germinated, the weed establishes parasitic attachments with the root of the host and starts deriving all nutrients from the host.

There are other types of weeds that multiply through roots, corms and stems. Weeding only cuts off the tops but the bottom continue consuming the nutrients and water applied for the maize. These should be controlled early before the beginning of the season as later attempt to control them may enhance chances of damage to the crop.

Methods of Weed Control:

Crop rotation:

Rotation of maize with leguminous crops such as cowpea and beans will help to reduce Striga in the fields. The striga is not adapted to the root system of the leguminous plants and will therefore die. However, this cannot completely eradicate striga because seeds can stay viable in the soil for a long time.

Proper spacing:

If crops are planted at recommended spacing of 60cm/70cm between rows and 20cm/25cm/ between plants depending on variety, the plants cover the ground quickly reducing the need for weeding. To ensure good yields, weed-free conditions should be maintained for first 10 weeks.

Timely planting:

Maize planted at the right time has vigorous growth and could be well established before the growth of weeds. The seeds should be planted at the earliest opportunity so that they can establish before weeds develop.

Hoeing and hand pulling:

Hoeing is the weed control method commonly used by small scale farmers. This is commonly followed by hand weeding to remove the weeds that will establish after hoeing.

Improving soil fertility:

Application of fertilizers or adopting any other soil fertility improvement practice such as using FYM/ vermicompost/poultry manure will enable the maize plants to have quick and vigorous growth, which will cover the ground and suppress weeds at an early stage.

Good seed:

Planting must be done with improved seeds of good quality recommended seeds that are free from weeds. It is always advisable to use treated seed bought from a recognized Agency.

Mechanical methods:

This involves the use of simple farm tools and implements such as hoes and weeders with a tilling depth of 3-5 inches, weeding width of 18-27 inches and operated through 12-16 tynes is a suitable substitute for manual hoeing. At the time of last hoeing, earthling up should be done properly which results in better anchorage of the crop.

Chemical methods:

This method of weed control makes use of herbicides. Application of Atrazine (Atratraf 50 wp, Gesaprim 500 fw) @ of 1.0-1.5 kg a.i ha^{-1} in 600 litre water, being a selective and broad-spectrum herbicide in maize checks the emergence of wide spectrum of weeds then followed by one hoeing 50 DAS are effective way for control of many annual and broad leaved weeds. While spraying, following precautions should be taken care by the person during spray, he should move backward so that the Atrazine film on the soil surface may not be disturbed. Preferably three boom flat fan nozzle should be used for proper ground coverage and saving time. One to two hoeing are recommended for aeration and uprooting of the remaining weeds, if any. While doing hoeing, the person should move backward to avoid compaction and better aeration.

Irrigation:

Most of the maize area is rainfed. If possible give at least three irrigations at the most critical periods i.e. at knee high, silking and grain filling stages.

Harvesting:

Cobs are harvested at 16% grain moisture when leaves turn completely brown and silk dries in case of normal maize, pop corn and quality protein maize. Picking of baby corn should be done 3-4 days after silk emergence. In sweet corn cobs should be picked about 25-30 days after flowering at around moisture level of 80% with sugar content of about 20 brix. Harvesting of stover or fodder maize at 50% flowering should be done with the help of sickles.

Dehusking and shelling:

Remove cob sheath of normal maize, pop corn and quality protein maize manually before sun drying and dry cobs in open sun properly. After proper drying of cobs, grains should be separated with the help of manual maize sheller or electric operated maize sheller.

Common Diseases of Maize and their Management:

Common Diseases of Maize:

Seed Rots & Seedlings Blights:

Causal organisms: *Pythium sp., Diplodia sp., Fusarium sp.*

Symptoms:

Above-ground symptoms of these diseases are yellowing, wilting and death of leaves. There may be confused with mechanical or chemical injury or insect damage. Examination of parts in the ground is, therefore, necessary for accurate diagnosis.

Seed Rot:

Causal organisms: *Pythium sp., Diplodia sp., Fusarium sp.*

Symptoms: Rotting of seeds before germination takes place

Damping off and seedling blight:

Causal organisms: *Pythium sp., Diplodia sp., Fusarium sp ., Penicillium sp.*

Symptoms:

Soft rot of stem tissues (mesocotyl) near the ground level and water soaking of seedling tissues occurs. The rotted area may be dark with sporangia and oospores in the tissues (*Phythium*), or with whitish grey (*Diplodia*), white-to-pink (*Fusarium*) or bluish (*Penicillium*) mycelium and masses of spores.

Seedling Wilt:

Causal organisms: *fusarium sp., Helminthosporium maydis.*

Symptoms:

A grey colouration starts at the leaf tips and extends rapidly to the whole leaf, causing complete collapse of seedlings in 24 – 48 hours. This symptom is suggestive of kernels infected with *Helminthosporium maydis* (race T), especially when no fungus can be isolated from infected leaves.

Southern or Maydis Leaf Blight

Causal organism: *Helminthosporium maydis*

Symptoms:

Elongated to elliptical or spindle shaped lesions develop on leaves between the veins which are yellow green in colour surrounded by dark brown borders. These lesions usually develop on leaves but may also appear on stalk, leaf sheath, ear husk, shank, ear and cob. A black felty mould may cover the affected kernels. Ear and cob rot can also occur with substantial losses in harvesting and shelling. Early shank invasion may cause premature death of the ear and possible ear drop.

Northern or Turcicum Leaf Blight

Causal organism: *Exserohilum turcicum*

Symptoms:

The initial symptoms appear on lower leaves as elliptical, grayish-green or tan lesions which measure 25–150 mm in length. The disease progresses upwards on the plant. Severe infection causes premature death and plants appear grey that resemble frost or drought injury. In damp weather, a large number of grayish black spores are produced on the lesions, often in concentric or target-like zones. The ears are not infected, although lesions may be formed on the outer husks. Disease development is favoured by moderate temperature (18-27^{0}C) and heavy dew during growing season. It is retarded by dry weather. If the disease is established before silking, losses in grain yield up to 50% may occur. If infection is delayed until six weeks after silking, yield losses are minimal.

Yellow Leaf Blight or Phyllosticta Leaf Spot

Causal organism: *Phyllosticta* sp.

Symptoms:

The initial lesions are rectangular to oval shaped and yellow to cream or tan-coloured, sometimes surrounded by chlorotic tissue, which first appear on lower leaves, especially on the outer-half. Lesions vary in size, averaging 3 to 13 mm, and may coalesce causing leaf blight. Leaf sheaths and outer husks are also susceptible to infection. Pycnidia, a distinguishing characteristic, develop in the lesions and extrude conidia under moist conditions. Infected plants turn yellow and may either die or remain stunted. Disease development is favoured by cool wet weather.

Downy Mildews

Causal organism: *Peronosclerospora sp., Sclerophthora* sp. or *Sclerospora* sp

Symptoms:

The symptoms caused by these fungi are somewhat similar and include chlorotic streaking, mottling, stunting, malformation of ears and tassels and excessive tillering. The symptom expression is greatly affected by plant age, species of pathogen involved and the environment. *Sclerophthora* produces excessive tillering (6-10 tillers per plant), rolling and twisting of upper leaves and partial or complete proliferation of tassel to a mass of leafy structures called ‘crazy top’. *Sclerophthora* (brown strips) produces narrow, 3-7 mm wide chlorotic or yellowish stripes on leaves which are delimited by veins that later become reddish to purple. *Sclerospora* produces chlorotic streaking or striping as well as stunting. Leaves may be thick, corrugated and fragile. *Peronosclerospora* (sorghum downy mildew) in systemically infected plants cause chlorosis in leaves and abnormal seed setting. The chlorotic area of a leaf always includes base of the blade (half leaf symptom) and later progresses further covering the whole blade. Leaves tend to be narrow and erect. Localized lesions may also be seen.

Common Smut:

Causal organism: *Ustilago maydis*

Symptoms:

Smut galls are at first covered with a glistening, greenish-white to silvery white tissue. The interior of these galls darken and turn into masses of powdery dark olive-brown to black spores, except for galls on the leaves. As the galls mature, they may reach 15cm in diameter and become hard and dry but do not rupture. Plants with galls on lower stalks may be barren or may produce several small ears. High N levels or heavy manure applications, high temperatures (26-34^{0}C) and injuries due to hail or sand storms predispose the host to infection.

Common Rust

Causal organism: *Puccinia* sp.

Symptoms:

Pustules (uredinia) are abundant on leaves and frequently occur in bands. Uredinia sporulate on both leaf surfaces 7 days after infection. The pustules are circular to elongate in shape, golden brown to cinnamon brown in colour and sparsely scattered over both leaf surfaces. Later they become brownish black as the plant matures and teliospores develop. Chlorosis and death of leaves and leaf sheaths may result from severe infection.

Management of maize Diseases

Field sanitation:

All the diseased plant debris should be thoroughly collected and destroyed by burning. Rogue out the diseased / smutted plants

Seed selection:

Collect healthy unbroken, disease-free seed from field. Seed of tolerant cultivars must be grown, wherever available

Planting spacing:

Close spacing is likely to predispose the crop to fungal infections so proper planting distance be maintained

Seed treatments:

Treat the seeds with any one of the following fungicide viz., mancozeb 75 WP or captan 50 WP or metalaxyl MZ 72 WP @ 2-3 g / kg seed

Foliar spray:

- Spray the crop at vulnerable growth stages with specific disease treatment, repeating the sprays at 15-20 days intervals.
- For the control of leaf blight and leaf spots crop should be sprayed either with mancozeb 75 WP @ 0.3% or with hexaconazole 5 EC @ 0.03%
- For downy mildew the crop should be sprayed either with mancozeb 75 WP @ 0.3% or with metalxyl 72 MZ @ 0.25%
- For rust and smut diseases spray the crop with triadimifon 25 WP @ 0.05%.

Common insect pests of maize and their management:

Cut worm (*Agrotis ipsilon***)**

It is one of the serious pests of maize in Kashmir valley. The caterpillars feed on young plants by cutting them off a little below or above the surface of soil. It destroys many more plants than it feeds upon, leading to reduction in plant stand and yield. The pest causes damage to the crop from 2nd week of April to 3rd week of June and its incidence is recorded up to July in maize crops at higher altitudes.

Economic threshold level:

When 3% or more of the plants are cut or 2 or more cutworm per 100 plants is observed or 0.4 larvae/m^2 is considered as ETL at which control measures should be initiated.

Management:

- Crop rotation with non host crops reduces the pest infestation by interrupting the continuity of the food chain e.g. maize should be rotated with other crop like pulses.
- Seed treatment of maize either with imidacloprid 200 SL (Gaucho) @4 ml/kg of seed or carbosulfan 25 ST (Marshall) @ 30 gm/kg of seed or deltamethrin 2.8 EC (Decis) @ 36 ml/kg of seed are very effective in reducing the crop damage.

- Higher seed rate of 30-40 kg/hectare is recommended in compensating the plant damage caused by the cutworm in maize. This should be followed by thinning to maintain required plant population in case cutworm damage is not severe.
- Early sowing of maize (2^{nd} to 3^{rd} week of April) reduces the damage.
- Ploughing and presowing weeding in the fields 15 days before sowing of maize reduces cutworm damage.
- Under heavy infestation, application of carbofuran 3G @ 32.5 kg/ at the time of sowing is most effective in managing cutworm.
- Deep summer ploughing helps to expose pupae/larvae to scorching heat and bird predation.
- Installation of light traps @ 5 traps per hectare.
- Use of resistant varieties.

White grub (*Holotrichia* spp., *Adoretus* spp. and *Brahmina* spp.):

Grubs of the pest feed on roots, causes wilting and finally death of the plant. The adult beetles defoliate the crop during the night hours as they are voracious feeders. This pest is active from March to October.

Management:

- Install light traps from April-July so that mass beetle emergence period is established in the area and application of insecticides on host plant is carried out at right time.
- Spray chlorpyriphos 20 EC @ 100ml/100 lit of water or endosulfan 35 EC 140 ml/ 100 lit of water during mass beetle emergence period on host trees/shrubs etc.
- Shaking of young non-bearing trees/shrubs at dusk during mass beetle emergence period and collection and destruction of the adult beetles.
- Apply carbofuran 3G @ 32.5 kg/ ha in the soil during the last ploughing of the field or quinalphos 10% dust or carbaryl 10% dust @20-25 kg/ha before sowing of seed.
- In case of heavy grub population in the soil, drench the field either with cypermethrin I0 EC @100 ml/100 lit of water or chlorpyriphos 20 EC @ 300 ml/100 lit of water.
- After 20 days of insecticidal drenching, mix 4.5 Kg of *Beauveria bassiana* in 1000 litres of water drench one hectare of land.

- Seed treatment of maize either with imidacloprid 200 SL (Gaucho) @4 ml/kg of seed or carbosulfan 25 ST (Marshall) @ 30 gm/kg of seed or deltamethrin 2.8 EC (Decis) @ 36 ml/kg of seed shall take care of cutworm as well as white grub.

Stem borer (*Chilo partellus*):

The freshly hatched caterpillars begin to feed on tender leaves at seedling stage, symptoms of pinhole, windowing and finally drying of central whorl and causing dead heart, resulting in wilting and dying of infested plants. In older plants it cuts central leaves and also feed from margins of the leaves. Presence of perforated terminal leaves is an indication of infestation. Maximum activity of stem borer is recorded between 18th June (10 DAG) to 29th June (30 DAG) and activity continued till August (45 DAG). The pest remains active from May to September.

Management:

Remove and burn all the left over stubbles and trash from the field after harvesting of the crop which harbor borer and act as source of infestation for the next crop.

- Roughing of infested plants and removal of dead heart.
- Growing of resistant varieties.
- Deep ploughing and proper spacing.
- Spray endosulfan 35 EC@ 280 ml/ 100 lit of water at 15 DAG.
- Whorl application of carbofuran 3G @ 3-5 granules/whorl 15 days after germination.
- Application of *Trichogramma chilonis* @ 1.5 lac/ha at 15 days after germination followed by second application after two weeks.

Army worm (*Mythimna separata*):

It is a sporadic pest. The pest mostly attacks the crops at the whorl forming stage. Young larvae feed on plant whorl, while as, grown up caterpillars feed on other leaves leaving mid rib and skeletonise them. The pest remains active from April to June.

Management:

- Uproot the stubbles of previous crop.
- Under severe infestation spray endosulfan 35 EC @ 140 ml/ 100 lit of water or quinalphos 25 EC @ 100 ml/100 lit of water.

Maize leaf Aphid (*Rhopalosiphum maidis*):

Both nymphs and adult suck the sap from the tender underside of leaves. Tender shoots are punctured and sap is sucked resulting in yellowish patches and ultimately wilting of plants. It also transmits maize dwarf mosaic virus. This pest remains active from June to September.

Management:

- Growing of resistant varieties.
- Use balanced dose of fertilizers.
- Encourage conservation of natural enemies such as *Coccinell*a *septumpunctata* or *Chrysoperla carnea*.
- Soil application of insecticides for the management of cut worm will also check aphid population initially. Later foliar spray either with dimethoate 30 EC @ 100 ml/ 100 lit of water or methyl-o-demeton 25 EC @ 80 ml/100 lit of water.

CHAPTER 3
VARIETAL PROFILE OF MAIZE VARIETIES OF SKUAST-KASHMIR RECOMMENDED FOR JAMMU AND KASHMIR STATE

Maize is one of the three most important food grain crops in the world, the others being rice and wheat. It is utilized as human food, livestock and poultry feed, raw material for a large number of industries products and as fodder. It is a staple food in 22 countries, two thirds of the produce is consumed as feed, and a very large number (>3500) products/bye-products can be derived from it. In Kashmir province bulk of the maize area is confined to the districts of Kupwara, Baramulla, Budgam and Anantnag. Major constraint for maize cultivation primarily involves predominance of cultivated land races, non-availability of vital inputs, in accessibility, scattered and small holdings and cultivation of maize over a wide range of environmental conditions and mostly under rainfed conditions.

Maize research programme of the university has been instrumental in developing area specific maize cultivars with enhanced yields and resilience to various biotic and abiotic challenges. Number of high yielding varieties like C6, C15, C8, Super-1, Shalimar KG-1, Shalimar KG-2, Shalimar Maize Composite- Series, Shalimar Normal and specialty corn variety series has been released by SKUAST Kashmir from time to time with the yield potential ranging from 4-7 tonnes per hectare suited to various altitudes of the state. These varieties have provided a great impetus to overall maize scenario of the valley. However, the genetic potential of the improved varieties is at least three times of the present average of the state. Below is the list of varieties released by SKUAST Kashmir to effectively augment livelihood security of maize farmers of Kashmir living in potential maize niches

Sr. No.	Variety	Ecology	Silent features	Maturity	Yield
1	Composite C -6 (C6) (1976)	Lower belts of Kashmir Valley and higher reaches of Jammu region (1500-1800 m amsl).	Plants medium tall, vigorous with ear placement at reasonable height. Leaves deep green with narrow apex. Stilt roots strong. Ears medium thick with compact green husk cover. Tassel branched and semi-compact. Silk predominantly light green.The variety is resistant to *Turcicum blight* under field conditions.	Matures within 155-160 days in temperate zone and 125-130 days in intermediate zone.	Yield potential is 45-50 q ha^{-1} under suitable management conditions.
2	Composite C–15 (C15) (1976)	Higher belts of Kashmir Valley and Jammu region.	Plants tall, vigorous with air placement at reasonable height. Leaves deep green with narrow apex. Stilt roots strong. Ears medium thick with compact green husk cover. Silk predominantly light green. Grains bold, orange yellow. The variety is resistant to *Turcicum blight* under field conditions. The plant does not lodge and escapes stem breakage under high fertility conditions.	Matures within 155-160 days in temperate zone and 125-130 days in intermediate zone. Early maturity.	Yield potential is 45-50q ha^{-1} under suitable management conditions.
3	Super-1 Mansar (1978)	Recommended for cultivation in all the zones of J&K State	Plants tall, vigorous with air placement at reasonable height. Leaves deep green. Stilt roots strong which make the plant lodging resistant. Ears medium thick with compact green husk cover. Silk predominantly light green. The variety is resistant to *Turcicum blight* under field conditions. The plant does not lodge and escapes stem breakage under high fertility conditions.	Matures within 155-160 days in temperate zone, 125-130 days in intermediate zone and 110-115 days in plains.	Yield potential is 50-60q ha^{-1} under suitable management conditions.

4	Composite C–8 (C8) (1996)	Irrigated foothills of Kashmir Valley and higher reaches of Jammu region (1500-1800 m amsl) and mid elevations (600-1000 m amsl) of Poonch, Rajouri and Udhampur districts	Plants medium tall, vigorous with air placement at reasonable height. Leaves dark green with narrow apex. Stilt roots strong. Ears long and medium thick with compact green husk cover. Tassel branched and semi compact. Silk predominantly light green. The variety is resistant to *Turcicum blight* under field conditions. The plant does not lodge an escapes stem breakage under high fertility conditions.	Maturity period ranges between 150-155 days in Valley /higher altitudes of Jammu and 110-115 days in intermediate zone.	Yield potential is 40-50 q ha^{-1} under suitable management conditions.
5	Composite C–14 (C14) (1996)	Recommended for high altitude areas of J&K State from 5500-6500 ft. amsl	Plants medium tall (1.5 –2 m). Leaves narrow, green. Tassel lax and medium sized. Silk light yellow to purplish. Husk covers green, fully covered. Cobs medium sized with conical shape. Grains bold, orange to orange yellow, predominantly flint which makes them good for chappati preparations. The variety has high level of field resistance to major diseases especially *Turcicum* blight. The variety has a fair tolerance to stem lodging / breakage even under high fertility levels.	Early maturing-matures in 135-145 days in the Valley, 100-110 days in intermediate zone and 95-100 days in plains.	Average yield under normal conditions ranges between 50-55 q ha^{-1}.
6	Shalimar KG Maize-1 (2005)	Recommended for Cold Hills of Kashmir (above 6500 ft. amsl) especially Machil and Gurez areas.	Medium tall plants with strong internode anthocyanin pigmentation and resistant to lodging. Grains flint type, uniform light orange coloured with whitish yellow tip. Silk slightly purplish, cobs medium sized and conico-cylindrical in shape. It is tolerant to leaf blight, downy mildew and resistant to stem rot. It is also moderately tolerant to maize stem borer and Angoumois grain moth.	The variety is extra early and matures within 120-125 days.	The variety has a yield potential of 45-50 q ha^{-1}

7	Shalimar KG Maize-2 (2005)	Recommended for Cold Hills of Kashmir (above 6500 ft. amsl) especially Gurez and Machil areas.	Medium tall plants with strong tassel and silk anthocyanin pigmentation. Resistant to cold, lodging and shattering. Leaf angle wide. Grains flint type, uniformly light orange coloured with yellow sides and white yellowish tip. Cobs medium sized and slightly conical in shape. It is tolerant to leaf blight, downy mildew and resistant to stem rot. It is also moderately tolerant to maize stem borer and Angoumois grain moth.	The variety is extra early and matures within 120-125 days	The variety has a yield potential of 40-45 q ha^{-1}.
8	Shalimar Maize-3 (2009)	High altitudes of Kashmir between 1800-2250 m amsl. Timely sowing is necessary for having adequate moisture at article stages like tasseling, silking and grain filling.	Plant height 183.23 cm, length of cob 20.52 cm, cob diameter 4.45 cm, ear shape conico- cylindrical, grain type semi flint/ semident), colour of tip of grain yellow, colour of dorsal side of grain yellow. Moderately resistant to Turcicum leaf blight and common rust, resistant to stem borer and moderately resistant to cut worm.	Maturity group early (i) 135-145 days (1800-2000 m amsl) (ii) 145-155 days (2000-2250 m amsl	Yield potential is 50-55q ha^{-1} under suitable management conditions.
9	Shalimar Maize Hybrid-1 (2009)	High altitudes of Kashmir between 1800-2250 m amsl. Timely sowing is necessary for adequate moisture at critical stages like tasseling, silking and grain filling.	Plant height is 242.21 cm, length of cob 21.60 cm, diameter 3.87 cm, ear shape cylindrical- conical, grain type semi flint/ flint. Colour of the tip of grain is white. Moderately resistant to Turcicum leaf blight and rust, resistant to stem borer and moderately resistant to cut worm	Maturity group early (ik) 135-145 days (1800-2000 m amsl) (ii) 145-155 days (2000-2250 m amsl)	Yield potential is 65-70q ha^{-1} under suitable management conditions.

10	Shalimar Maize Composite-4 (2009)	Mid altitudes of Jammu & Kashmir between 1650-1800m a.m.s.l (irrigated /rainfed). Timely sown with assured moisture at critical growth stages, like Knee high, tasseling, silking and grain filling stage. Integrated nutrient management system should be followed to maintain good nutrient status of soil	Plant height is 190 cm, length of cob 18 cm, diameter 4.2 cm, ear shape cylindrical- conical, grain type is flint. Colour of the tip of grain is yellow. Resistant to turcicum leaf blight and common rust. In Insect pests it is moderately resistant to stem borer and aphid	Medium maturity i.e 140-145 days (1650-1800 m a.m.s.l) ii.100-105 days (1200-1300 m a.m.s.l)	Yield potential is 60-65q ha^{-1} under suitable management conditions
11	Shalimar Maize Composite-5 (2013)	Timely sown crop with adequate moisture at critical growth stages like tasseling, silking and grain filling. Soil should have good quantity of organic manure and applied with balanced dose of fertilizer. Best performing areas mostly fall in higher elevations of Valley	First QPM Variety for Kashmir region. Medium plant height with conical ears placed at medium height with broad leaf blades. White semi flint grains with cap and strait Kernel row arrangement. Moderately resistant to *Turcicum* leaf blight and common rust. The variety is also resistant to stem borer and moderately susceptible to cut worm. The variety has high tryptophan, lysine & sugar contents. The variety has good seedling vigour with fair degree of tolerance to cold and drought.	Early i) 135-140 days(1800-2000m asl) ii) 150-155 days (2000.2250m asl)	Yield potential is 55-60q ha^{-1} under suitable management conditions in recommended zones of cultivation.

12	Shalimar Maize Composite-6 (2013)	Timely sown with assured moisture at critical growth stages, like Knee high, tasseling, silking and grain filling stage. Integrated nutrient management system should be followed to maintain good nutrient status of soil.	The plant type of this variety is tall best suited under high altitude areas because of its early maturing nature. Seeds are yellow and flint placed on stoutly developed ears. Resistant to Turcicum leaf Blight and Moderately resistant to stem borer and aphids.	It matures in 135-140 days in the Valley and is recommended for higher elevations up to 2400 meters.	Yield potential is 55-60q ha^{-1} under suitable management conditions in recommended zones.
13	Shalimar Maize Composite-7 (2013)	Suitable for most of the plains of Kashmir valley and good grain and stover recovery	Plants are 195 cm tall with good biomass and dark green foliage and yellow flint bold grains. Resistant to Turcicum leaf Blight and Moderately resistant to stem borer and aphids. The variety shows fair degree of moisture tolerance.	Mid altitudes of Jammu & Kashmir between 1650-1800 m a.m.s.l (irrigated/rainfed)	Yield potential is 55-60q ha^{-1}under medium altitude zones of Kashmir Valley
14	Shalimar Maize Hybrid 2 (2013)	First yellow coloured medium maturity hybrid suitable for plans of Kashmir Valley	Parental line of this hybrid KDM 500 derived from CM 128 after selection and stabilization for adoption for valley conditions and another parent KDM 347 derived from EH-30624. Variety is with good biomass, timely maturity, high yield with good protein content. Plants are tall and vigorous with broad dark green leaves. Grains are yellow flint and with high test weight. The hybrid possesses resilience against major biotic pressures	Mid altitudes of Jammu & Kashmir between 1650-1800 m a.m.s.l (irrigated/rainfed)	Yield potential is 70-75q ha^{-1} under medium altitude zones of Kashmir Valley

15	Shalimar Popcorn1 (2016)	First pan India Popcorn release from SKUAST-Kashmir. Small yellow flint grains with wide adaptability across all ecological zones of India	Early maturing medium statured plants with pigmented anthers, dense spikelets and small yellow flint grains. Early maturing, responsive to fertilizer application, resistant to lodging with an optimum seed rate of 16 kg per hectare Moderately Resistant to Banded Leaf and Sheath blight and Fusarium Stalk Rot	Recommended across India cultivation	Yield potential is 35-40q ha^{-1} yield recorded average across all AICRP testing centers of India
16	Shalimar Mazie QPM-1 (2017)	Single cross hybrid KDQH-49 was developed by crossing KDQPM-13 used as female Parent with KDQPM-14 used as Male parent recommended for medium altitude plains of Kashmir for timely sowing conditions.	Medium tall plant with good foliage traits and moderate resistant reaction to major diseases and pests prevalent in maize niches of Kashmir. Hybrid is with good biomass, timely maturity, good tryptophan and lysine content. The hybrid is having yellow and flint grains.	Mid altitudes of Jammu & Kashmir between 1650-1800 m.a.m.s.l (irrigated/rainfed)	Average grain yield of 55-60 quintals per hectare with ample quality protein harvest
17	Shalimar Sweet corn 1 (2017)	Timely sown with assured moisture at critical growth stages. Suitable for medium altitude zones of Kashmir Valley.	Plants are of medium height of 170-175 cms with conico cylindrical cobs and yellow shrunken grains on husk browning and plump shinny yellow grains at green cob stage. Green cob kernels are having brix value of 21 per cent. The variety is having very high pollen production and seed set. Moderate tolerance to most of diseases and pests.	Medium maturity 125-135 days (1650-1800 m.a.m.s.l)	Green cob yield of 85 quintals per hectare

CHAPTER 4

SEED PRODUCTION TECHNOLOGY IN MAIZE

Maize ranks third in importance among India's cereal crops, covering more than eight million hectares and contributing over twenty million tons annually to the nation's grain supply. In addition to serving as an important food staple for an economically vulnerable segment of the population, maize also ranks first in importance as a feed crop and further more is an important source of raw material used in numerous industrial processes. The maize sector in India has undergone dramatic changes in recent years. One of the most significant has been the rapid growth of the private seed industry. Maize seed companies, once uncommon, have sprung up in many important maize seed producing states and today offer farmers a wide range of improved open pollinated varieties (OPVs) and hybrids. Private companies have captured a significant share of the national market for maize seed and all signs point to continuing expansion of this market share in the future. Maize is scientifically called *Zea mays* and it belongs to family Poaceae. It is one of the most important cereal crops in the world grown over an area of 162 mha with a production of 870mt. It is the crop with the highest productivity. The first coordinated crop improvement project was launched on maize by ICAR in 1957. In India, Portuguese introduced maize during the seventeenth century. In India major area of crop is confined to Gujarat, Rajasthan, Punjab, Haryana, Madhya Pradesh, Andhra Pradesh, Haryana, Jammu & Kashmir Bihar and Karnataka.

Maize hybrids are more attractive to seed industry for the economic reasons namely, higher profit margin for seed producers and farmers. Production of high quality seed is the primary objective of a seed programme. Care is to be taken to fix certification standards for various stages of seed multiplication to produce quality seed without hampering seed production.

Floral biology of Maize:

The distinguishing feature of maize flower is the separation of the sexes among its flowering structures. i.e., a monoecious plant. Maize produces male inflorescences (tassels) which crown the plant at the stem apex, and female inflorescences (cobs or ears), which are borne at the apex of condensed, lateral branches protruding from leaf axils. The male (staminate) inflorescence, a loose panicle, produces pairs of free spikelets each enclosing a fertile and a sterile floret. The female (pistillate) inflorescence, a spike, produces pairs of spikelets on the surface of a highly condensed rachis (central axis, or "cob"). Each of the female spikelets encloses two fertile florets, one of whose ovaries will mature into a maize kernel once sexually fertilized by wind-blown pollen.

Anthesis and Pollination:

Maize is an example for protandry. Pollen shedding begins 1-3 days before the silks emerge from the cob. It is estimated that a normal plant produces 2,50,00,000 pollen grains. Pollen is viable for 12-18 hours. Silk remains receptive for 8-10 days. Anthesis continues up to 2 weeks. The silk will be pinkish and sticky at the beginning (receptive) after fertilization it will be chocolate or brown colour.

Maize Hybrid seed production consists of three stages. They are:

1. **Breeder Seed:** Production of breeder seed is directly controlled by the plant Breeder. This stage of seed production is called "Breeders seed". It is generally produced in limited area either by hand pollination or in isolation.
2. **Foundation seed:** Foundation seed generally consists of production of single crosses by sowing male and female parents. These parents will be sown in 2:4 row ratios. De-tasselling will be done in female rows. All off types, diseased and rogues if any found will be removed. Certification standards will be maintained under the guidance of monitoring team consisting of National Seed Corporation Agencies, Certification, Agencies, Breeders and I.C.A.R. Nominee.
3. **Certified seed:** Certified seed i.e. the last stage of maize hybrid seed production. Male and female single crosses generally sown on 2:6 ratio. Female plants are detasseled. All off types, diseased and rogues if any foun d will be removed. Certification standards will be maintained under the guidance of monitoring team. The seed obtained on female rows is called certified seed. This seed is labeled as hybrid seed and sold to the farmers for commercial cultivation.

Hybrid seed production in maize:

- **Crossing technique:** Manual emasculation by detasseling
- **Detasseling:** Removal of male inflorescence from the monoecious crop
- **Time for detasseling:** The tassel should be 1-2 days old after emergence. Hence the tassel should be removed before the shedding of pollen

Detasseling:

Detasseling is the removal of tassel from female parent. Detasseling is done when the tassel emerged out of the boot leaf, but before anthers have shed pollen. Anthers take 2-4 days to dehisce after complete emergence. Only in few cases, the anthers start dehisce before its complete emergence. In such case detasseling should be done earlier. Detasseling is done every day from the emergence of tassel upto 14 days.

Method:

- Hold the stem below the boot leaf in left hand and the base of the basal in right hand and pull it out in a single pull.
- Grasp entire tassel so that all the pollen parts are fully removed.
- Do not break or remove leaves as removal will reduce yields and will result in lower quality of seed.

Precautions to be adopted during detasseling:

- No part should be left on the plant as it causes contamination.
- It should be uniform process done daily in the morning in a particular direction.
- Do not break the top leaves as the field may be reduced due to the earning of source material to accumulate in sink [seed] as removal of 1 leaf course 1.5% loss 2 leaves 5.9% loss and 3 leaves 14% loss in yield.
- Detassel only after the entire tassel has come out and immature detasseling may lead to reduced yield and contamination.
- Mark the male rows with marker to avoid mistake in detasseling
- Look out for shedders [shedding tassel] in female rows as the may cause contamination.
- After pulling out the tassel drop it there itself and bury in soil. Otherwise late emerging pollen from detasseled tassel may cause contamination.
- Do not carry the tassel through the field as any fall of pollen may lead to contamination.
- Donot practice, improper, immature and incomplete detasseling.

Improper detasseling: A portion of the tassel is remaining in the plant while detasseling.

Immature detasseling: Carrying out detasseling work when the tassel is within the leaves.

Incomplete detasseling: The tassel is remaining in lower or unseen or unaccounted in within the whole of leaves. There should not be any shedding tassel.

Shedding tassel: Either full or part of tassel remain in female line after detasseling and shedding pollen which may contaminate the genetic purity of the crop.

System of Hybrid seed production:

Detasseling (Manual creation of male sterility)

Types of hybrids:

Single cross hybrid:

- It is a cross between 2 inbreds A x B.
- A genotype will be detasseled and crossed with B genotypes e.g

- SMH-1- CML 349 x CML 354
- SMH-2 – KDM 347 x KDM 500
- DHM117- BML 6 x BML 7

Double cross:

- It is a cross between two single crosses.
- It is a cross between 2 hybrids (A x B) x (C x D) (A x B) single cross hybrid will be produced by detasseling A and by crossing with B (C x D) hybrid will be produced by detasseling C and crossing with D.
- Then (A x B) will be detasseled and crossed with (C x D) hybrid.

Example:

Ganga 2: (CM 109 x CM 110) x (CM 202 x CM 111)

Ganga 101: (CM 103 x CM 104) x (CM 201 x CM 206)

COH3: (UMI 101 x UMI 130) x (UMI 90 x UMI 285)

Three way cross

- It is a cross between a single cross and an inbred.
- It is first generation resulting from the crossing of on approved inbred line and a certified open pollinated variety A x variety)
- A will be detasseled and allowed for crossing in the variety.

Example	Ganga -5	(CM 202 x CM 111) x CM 500.
	COH (M) 4 : (UMI 90 x UMI 285) x UMI 112	
Double top crosses	The first generation resulting from the controlled	
	crossing of a certified single cross and a certified	
	open pollinated variety.	
	(A x B) x variety	
	(Ax B) will be detasseled and crossed with a variety	

Field standards for isolation in metres:

(Modification based on situation):

	Foundation stage	**Certified stage**
Same kernel color	400	200
Different kernel colour	600	300
Field of single cross / inbreds not confirming to varietal purity	400	200
Single cross with same male parent confirming to varietal purity	5	5
Single cross with other male parent not confirming to varietal purity	400	200

- Differential blooming dates are permitted for modifying isolation distance provided 5.0% or more of the plants in the seed parent do not have receptive silk when more than 0.20% of the plants in the adjacent field within the prescribed isolation distance are having shedding pollen.
- In hybrid seed production (certified seed stage) alone the isolation distance (less than 200 meter) can be modified by increasing the border rows of male parent, if the

kernel colour and texture of the contaminant are the same as that of the seed parent.

The number of border rows to be planted all around the seed field to modify isolation distance less than 200 m shell also be determined by the size of the field and its distance from the contaminant as shown below.

Requirements of Border Rows for spatial isolation:

Area in ha.	Isolation distance (m)	Border rows
< 4 ha	200	1
< 4 ha	150	5
< 4 ha	100	9
< 4 ha	50	13
10-12 ha	180	1
10-12 ha	130	5
10-12 ha	80	9
10-12 ha	30	13
> 16 ha	165	1
> 16 ha	115	5
> 16 ha	65	9
> 16 ha	15	13

Seed production stages and production of parental lines / hybrids:

Stage of seed	Single Cross	Double Cross	Three way cross	Double top Cross	Top Cross
Breeder seed	A, B	A, B, C, D	A, B, C	A, B, Variety	A, variety
Foundation Seed	A, B	(AxB) (CxD)	(AxB), C	(AxB) Variety	A, variety
Certified seed	A X B	(AxB) x (CxD)	(AxB) x variety	(AxB) x Variety	Ax variety

Spacing Seeds are sown in ridges and furrows		
Hybrids	:	60x 25 cm
Seed rate	:	Female : 7 -10 kg ha-1

	:	Male : 3 -4 kg ha-1
Spacing area	:	Female : 60 x 20 to 75 x 30 depending on the area, Male :45 x 30 cm
Planting ratio		
Single cross	4:2	
Double cross	6:2	
3 way cross	6:2	
Border rows		a. Inbreds & single cross - 4 rows
		b. Others - 3 rows
Fertilizer		
NPK kg / ha	:	200 : 100 : 100
Basal	:	100 : 100 : 50
1st Top	:	50 : 0 : 0 (20th days -vegetative phase)
2nd Top	:	50 : 0 : 50 (Boot leaf stage at 45 days)
Foliar	:	DAP 2% at 50% flowering
In Zn deficient soil	:	ZnSO4 @ 25 kg ha-1

Roguing:

Should be done periodically based on position of cob, colour of silk, arrangements of seeds in cob, leaves etc. Shedding tassels are to be removed in roguing . It refers to the tassels in female parents rows, shedding pollen or that has shed pollen in hybrid maize plots. During field inspection a tassel whose main spike or any side branch or both have shed pollen or shedding pollen in more than 5 cm of branch length is counted as a shedding tassel during inspection the shedding tassels are taken into count for acceptance or rejection of production plot.

Field standard (%)		
	FS	CS
Off types	0.2	0.5
Shedding tassel	0.5	1.0 (when receptive silk is 5% or more)

Inseparable other crop	:	Nil (both stage)
Objectionable weed	:	Nil (both stage)
Designated diseases	:	Nil (both stage)

Field standards –specific

Specific factors	**Certified stage**
Off types shedding pollen when 5 % or more of seed parent in receptive silk	0 .50 %
Seed parent shedding pollen when 5 % of the seed parent is having receptive silk	1.0 %
Total of pollen shedding tassel including tassel that had shed pollen for all 3 inspections conducted during flowering on different dates	2 .0 %
Off types in seed parent at final inspection	0 .5 %
Number of inspections : Four	

Harvest

- Harvest when the moisture content falls to 20-25%
- Harvest male first and remove from the field and then harvest female

Threshing:

a. Dehusking: The husks are removed manually.

b. Cob sorting: Remove ill filled, diseased cobs and cobs having kernel colour variation.

Xenia:

The direct/visible effects of pollen on endosperm and related tissues in the formation of a seed colour. e.g. seed colour. In maize, the gene present in sperm cell contributes in the expression of colour of hybrid seeds.

Mataxenia:

Is the effect of pollen on the maternal tissues of seed.

Shelling:

Cob sorting should be the first operation it is a post harvest, evaluation for genetic purity. The sheath is removed and check for kernel colour, shank colour, diseased cobs, kernel arrangement. The cobs are shelled either mechanically or manually at 15-18% moisture content. Improper shelling leads to 48% damage to kernel. Growth of storage fungal Pericarp damage. Crack on pericarp can be identified by $FeCl_3$ or Tz test. Shelling is done mechanically using cob sheller and manually by rubbing with stones.

Drying:

Seeds are dried to 12% moisture content.

Grading:

Grade the seeds using 18/64" (7.28 mm) sieve.

Seed treatment:

Slurry treat the seeds with 8% moisture content either with captan or thiram 75% W.P. @ 70 g/100 kg with 0.5 litre of water. Treated seeds can be stored for 1 year in cloth bag.

Others: As in varietal seed production

Seed yield: 2.5 - 3.6 t/ha

Sr. No.	Parameters	Inbreds / Hybrids	FS	CS
1	Physical purity (%) (min)	98	98	98
2	Inert matter (%) (max)	2	2	2
3	Other crop seed (max)	5 kg^{-1}	5 kg^{-1}	10 kg^{-1}
4	ODV seeds (max)	5 kg^{-1}	5 kg^{-1}	10 kg^{-1}
5	Germination % (min)	80	80	90
6	Moisture content (%) (max)			
	a. Moisture pervious	12	12	12
	b. Moisture vapour proof	8	8	8

Production of Synthetic cultivars:

Breeding of cereal and other agronomic crops has contributed significantly to the growth of agribusiness worldwide. In normally self fertilized crops, new variability may be created by hybridisation, followed by the selection of desired cultivars in which desirable characteristics from two or more parents are combined. The type of hybrid cultivar obtained will depend upon the genetic background of the chosen parents as well on the method of selection used. A similar situation arises when new variability is artificially induced through mutations.

In pure-line theory of classic plant breeding, a pure line is defined as all the descendants of single homozygous individual by continued self-fertilization, resulting in a homogeneous cultivar. Hybridization, however, results in significant heterogenity. The multiplication of such heterogenous progeny in bulk to select homozygous individuals would be gigantic task. Most modern hybrid cultivars are, therefore, selected at an early stage (F_2) as subsequent lines and probably released at the F_8 and F_{12} generations. These are obviously not as homogeneous as a pure line.

Cultivars can also be selected by producing multilines. Whereas normal line selection seeks to produce a new cultivar on the basis of one line or a few lines that are very similar, multiline cultivars are essentially different from each other in their characteristics, such as resistance to pests and diseases or environmental stresses. Thus, by incorporating different sources of resistance, the newly synthesized cultivar is buffered against changes brought about by virulent pathognes. These cultivars are however, not very stable compared to those produced by the conventional methods of selection. A change in the prevalence of a virulent pathogen may eliminate certain lines from the cultivar. It is, therefore, necessary to return the cultivar to the plant breeder for its reconstitution. This may be advantageous, because it enables plant breeders to substitute new sources of resistance in the material.

Alternatively, the plant breeder can create a composite cross by bulking the F_2 generations of several crosses. The composite is allowed to develop for several generations during which natural selection may occur. If the composite is grown at more than one location, a locally adapted cultivar may be developed in time. The composite constitutes a gene pool from which the plant breeder can select a cultivar with desirable characteristics for further multiplication.

An alternative to the composite is the synthetic or artificial method of plant breeding in which a number of lines are put together by the plant breeder in predetermined proportions. A synthetic line generally has a limited life, because the proportions of the constituent lines are likely to change over number of generations. The plant breeder must plan for seed production of limited generation basis. This system can be extended by using mixtures of cultivars claimed to be advantageous in some species over a single cultivar, especially if different resistant genes are present in each cultivar. This method adds to the cost of mixing, which can be reduced by growing a seed crop for one or two generations after mixing before using it for crop production. A hybrid cultivar results from a controlled cross between a male and female parent, the seed being harvested from female parent only and used for crop production.

In self fertilized crop species, it is easy to produce hybrid cultivars if male sterile lines are available that can be used as female parents. There are certain substsnces that act as a gametocides, destroying the pollen of desired female parent, or as inhibitors that prevent pollen produced by the female parent from effecting fertilization. The advantage of the synthetic hybrid cultivar lies in heterosis. Special expensive measures are required to produce seed that is harvested from the female parent only. The resultant heterosis therefore must have a profitable effect to compensate for the cost of production of synthetic hybrid cultivars in the self-pollinating crop species.

In the cross-pollinated crop species, plant breeders look for parent plants that have good combining ability. These plants, when allowed to multiply together, produce a desirable combination of characteristics. Cross fertilization results in greater heterozygosity in these plants than in the self-fertilized plants and therefore less homogeneity. Each generation of an open pollinated cultivar is thus a mixture of hybrids. The open pollinated cultivars are generally grown for a limited number of generations and returned to the plant breeder's maintenance material after each cycle of seed production to produce commercial quantities of seeds.

Putting together a large number of parent plants and allowing random pollination to occur can create composites. A composite in a cross fertilized species is generally the product of the first generation of such random pollination.

Production of synthetic cultivars begins with a limited number of specific parents, which are permitted to interpollinate. The number of generations of multiplication is strictly limited so as to recreate the synthetic/artificial cultivar at the end of each multiplication cycle. As with the self fertilized species, synthetic hybrid cultivars of cross fertilized species are created by controlling pollination to ensure that seed is produced from a desired crossing. This can be achieved by the following methods.

1. By emasculating the female parent, as is done in monoecious plants like maize, by removing the male flowers before the release of pollens.
2. By using male sterility in the female line, so as to avoid the physical removal of male flowers.

3. By using self incompatibility. In this system, the seed crop is harvested as a whole, since all plants are contributing and receiving pollen. The self incompatibility, however, is not always complete, and there may be production of some inbred plants. With the excessive production of such plants, the advantage of heterosis in the subsequent crop is diminished.

The advantage of the synthetic hybrid cultivar in cross pollinated species is not restricted only to heterosis. Most hybrids are based upon inbred lines. Normally, cross fertilized plants require inbreeding for several generations to reduce heterozygosity and to include desirable genes in synthetic cultivars. A controlled cross between two such inbreds produces heterosis and desirable combination of genes in the form of a synthetic cultivar.

The major disadvantage of the production of synthetic cultivars is the higher cost of plant breeding and seed production, requiring considerable time consuming work to produce desirable inbreds, which alone can be used to synthesize new artificial hybrids. The final seed crop is not fully productive when male sterility or emasculation is used, because only the female parent is harvested for seed.

Therefore various other hybrids have been produced. The hybrid resulting from the cross of two inbred lines is a single cross, whereas the F1 resulting from the cross of two single cross hybrids as parents is known as a double cross. In a three way cross, an inbred is mated with an F1 hybrid. A top cross is the F1 resulting from a cross between an inbred or a single cross and an open pollinated cultivar. All of the forms of hybrid cultivars require a particular cycle of seed production to produce the seed used in crop production.

CHAPTER 5

MANAGEMENT OF STEM BORER (CHILO PARTELLUS SWINHOE) IN MAIZE

Maize (*Zea mays* Linn.) is one of the important cereal crop in the world both as food for humans, feed for animals and is also known as "Queen of Cereals" because of its high yield potential (Ali *et al.*, 2014). In India, maize is cultivated over an area of about 9.2 million hectares with an annual production of 23.67 million tonnes and productivity of 2.57 tonnes per hectare (Anonymous, 2015). Maize is ranked as the third most important cereal crop after wheat and rice (Khalili *et al.*, 2013). In the state of Jammu and Kashmir, it is cultivated over an area of about 0.31 million hectares with a production and productivity level of 0.46 million tonnes and 1.49 tonnes per hectare, respectively (Anonymous 2015). About 85 per cent of maize crop in the state is grown in rainfed areas and ranks second most important crop after paddy. Productivity of maize in Kashmir valley under rainfed conditions is 11.5 quintals per hectare as against 23.0 quintals per hectare in sub-tropics of Jammu (Anonymous, 2013). In India about 28, 11, 48, 12 and 1 per cent maize produced is used for food purpose, livestock feed, poultry feed, wet milling industry and seed, respectively (Siddiqui & Marwaha, 1993).

Among different crops, maize is versatile having high nutritive value, since it contains carbohydrates, vitamins, minerals and proteins. Besides, maize crop is rich in dietary fibre and calories. Maize is relatively short duration crop for the area of high altitude where chilling conditions and snowfall limits its growing period. It is considered as highest yielding cereal crop in the world and is of significant importance for countries like India where rapidly increasing population has already out stripped the available food supplies (Mghenyi, 2006).

In India, maize crop is being attacked by about 139 species of insect pests with varying degree of damage but, only a dozen of them are quite serious (Siddiqui & Marwaha, 1993). Among these, Khan *et al*. (1997) reported some lepidopterous pests such as stem borers a limiting factor as they infest the crop throughout its growth from seedling to maturity. They recorded seventeen insect species in two families of Pyralidae and Noctuidae as important pests of maize. Amongest these maize stem borer (*Chilopartellus* Swinhoe), coastal stalk borer (*Chiloorichalcociliellus* Strand), maize stalk borer (*Busseolafusca* Fuller), pink stalk borer (*Sesamia calamistis* Hampson) and sugarcane stalk borer (*Eldana saccharina*

Walker) are of greater importance. Further, the authors recorded that yield losses in maize due to stem borers varied widely in different regions from 25 to 40 per cent with respect to the pest population density and phenological stage of the crop. Maize stem borer is key crop destroyer and is known as one of the major biotic constraint in successful maize production worldwide (James, 2003). The pest has been reported to cause severe losses in maize crop throughout its geographical distribution and the yield losses of 75 per cent have been documented by the borer alone besides, crop may even fail if it remains uncontrolled (Latif *et al.*, 1960). In Kashmir province of Jammu and Kashmir state at DARS, Budgam it was reported that leaf infestation by maize stem borer occurred from 18^{th} to 28^{th} Standard Week (SW) during which the leaf infestation increased from 4.00 to 48.50 per cent (Hamid, 2015).

Lella and Srivastav (2013) reported that larvae of *C. partellus* after hatching feed on soft surface of the leaves and then enter the stem through whorl for feeding on the pith of the stem. The growth of the plants becomes stunted and resulting in dead hearts when attacked by *C. partellus* at their initial stages. The larvae migrate from other plants and enter the stem through lower nodes by making the holes. Stem borers pupate inside the stem and make exit holes before pupation for the emergence of adults. Sometimes, the larvae inside the stem enter the ears through the shank and damage the ears. The larvae of next generation of stem borer feed on tassels. There are five overlapping generations of *C. partellus* that can be found throughout the year in India. The fifth generation undergoes hibernation during winter from mid-October/November to mid-February/March. The first two or three generations damage the spring maize crop thereby, reducing the quality and yield of such an important crop.

A number of control techniques have been used to manage this pest but, due to heavy infestation and extensive damage, the chemical control is still the most important method. Host plant resistance against various pests including insects has remained a reliable source for pest management since the advent of modern agriculture. The use of insect resistant cultivar is an essential component of IPM which offers an economic, stable and ecologically sound approach to minimize the damage caused by the borers. There are many plant characters which are responsible for host plant resistance. The plant structures may influence positively as well as negatively on herbivores and their natural enemies (Afzal and Bashir, 2007). These characters may be divided into morphological and biochemical basis of resistance of the host plant which significantly exhibit resistance to *C. partellus* in maize and show variable degree of preference against the pest. However, bio-control agents such as parasitoids, predators and pathogens suppressed the population of *C. partellus* but, their activity is not enough to reduce the pest population below the economic threshold level (Divya *et al.,* 2009). Though some of the insecticides *i.e,* azadirachtin, dimethoate, carbofuran and imidacloprid have been reported to substantially suppress the pest population (Bhat and Baba, 2007) A single strategy cannot effectively control the pest hence, various components of IPM altogether are used to minimize misuse of hazardous pesticides and to reduce killing of different natural enemies and its impact on yield.

Integrated Pest Management of maize stem borer (*C. partellus* Swinhoe):

1. Use of resistant varieties:

Various resistant cultivars of maize that are locally available can be used for management of pest. Cultivars given below were screened at DARS, Budgam Kashmir for resistance against the pest and different levels of resistance were achieved, so the cultivars that are highly resistant and resistant can be effectively used in IPM programme for management of the pest (Rasool *et al.,* 2017).

Sr. No.	Genotypes	Numerical score	Reaction
1.	CM-133 CM-123	1	Highly resistant
2.	KDM-895A KDM-381A KDM-362B	2	Resistant
3.	KDM-402	3	Resistant
4.	CM-128 SMH-2	4	Moderately resistant
5.	SMC-3 KDM-72 C-6	5	Moderately resistant
6.	KDM-914A KDM-962A KDM-912A KDM-463	6	Susceptible

7.	C-15 KDM-322 KDM-1263 KDM-916A	7	Susceptible
8.	KDM-340A KDM-347 KDM-361A KDM-935A	8	Highly susceptible
9.	Basi-local	9	Extremely susceptible

2. Cultural control

Cultural practices include appropriate disposal of crop residues, time of planting, tillage and mulching, spacing, intercropping, removal and destruction of volunteer and alternative hosts, removal of borer-infested plants, fertilizer application and crop rotation. Destruction of crop residues and stubble to reduce stem borer infestations has been recommended. Early planting has been found to lower stem borer infestations. Intercropping sorghum with cowpea delayed *C. partellus* larval population build up.

3. Mechanical control

- Destruction of crop residues/stubbles before planting and removal of infested plants in early stage of the crop.
- Installation of light traps in the month of April in order to record seasonal variation in adult moth of maize stem borer. An experimental trail was laid at DARS, Budgam and the observations on moth catch in context to vegetative stage of crop indicated that the first catch was recorded in 17th SW (4th week of April) with mean moth catch of 5.00 moths/trap. Subsequently, a gradual increase in moth catch from 6.50 to 20.00 was observed corresponding to vegetative crop stage during 18th to 24th SW (1st week of May to 2nd week of June). Further it was reported that from vegetative to tasseling stage of crop *i.e.* 25th to 35th SW (3rd week of June to 5th week of August), the adult moth catch declined from 16.00 to 1.00 moths/trap after which no catch was observed and culminated altogether with the crop senescence. Thus, light traps can be used for suppression of pest incidence (Hamid, 2015).

4. Biological control:

Parasitoids and predators:

Parasitoids of interest include the egg parasitoids, such as *Trichogramma* spp., larval parasitoids, including *Cotesia sesamiae* (Cameron) (Hymenoptera: Braconidae) and *C. flavipes* (Cameron) (Hymenoptera: Braconidae) and pupal parasitoids, *Pediobius furvus Pediobius furvus* Gahan (Hymenoptera: Eulophidae). Among predators earwigs, ants, spiders, and ladybird beetles have been found to feed on the eggs, larvae and pupae of *C. partellus* (Seshu Reddy, 1998). In Uganda, Mohyuddin & Greathead (1970) reported the ants *Tetramorium guineense* Bernard (Hymenoptera: Formicidae) and *Pheidole megacephala* Fabricius (Hymenoptera: Formicidae) destroyed almost 90 % of eggs and first instar larvae of *C. partellus*. Application of *Trichogramma chilonis* @ 1.5lac/ha at 15 days after germination followed by second application after two weeks is recommended for control of pest

Microbial pathogens:

Nematodes:

Most studies of nematodes attacking *C. partellus* in Africa have been simply distribution records. Two genera of nematode, *Hexamermis* and *Panagrolaimus* belonging to the families, Mermithidae and Panagrolaimidae have been reported from Kenya (Otieno, 1986).

Protozoa:

Nosema partelli Walters and Kfir, is endemic to South Africa and is a widespread disease in field and laboratory populations of *C. partellus* in the region. However, it was only infective in laboratory cultures and less active under field conditions. *Nosema* sp, has a great potential as both a cheap and effective control agent in Kenya (Odindo *et al*., 1993).

Bacteria:

Attempts at using *Bacillus thuringiensis* Berliner against *C. partellus* have been reported by Berger (1981) in Mozambique. In Mozambique, various combinations of *B. thuringiensis* with chemical insecticides were used. However, it was concluded that this type of treatment was too expensive. In South Africa, Hoekstra & Kfir (1997), reported *B. thuringiensis, Streptococcus* sp. and *Serratia* sp. infecting a field-collected population of *C. partellus*.

Viruses:

Studies made in Kenya and South Africa identified granulosis viruses, polyhedral inclusion bodies, cytoplasmic polyhedrosis virus and entomopox virus (Hoekstra & Kfir, 1997). In Egypt, infection by nuclear polyhedrosis virus of *Chilo agamemnon* Bleszynski (Lepidoptera: Crambidae) (Abbas, 1987), had a detrimental effect on the development of a larval parasitoid, *Habrobracon brevicornis* Wesmael (Hymenoptera: Braconidae). In India, granulosis viruses have been used with some success for the control of *Chilo sacchariphagus* Stramineelus (Caradza) (Lepidoptera: Pyralidae) and *Chilo infuscatellus* Snellen (Lepidoptera: Pyralidae) (David and Easwaramoorthy, 1990).

Fungi:

Metarhizium anisopliae (Metschnikoff) Sorokin and *Beauveria bassiana* (Balsamo) Vuillemin have been isolated from infected *C. partellus* in South Africa and Kenya (Hoekstra and Kfir, 1997). *Entomophthora* sp. was the most common fungal pathogen of *C. partellus* in South Africa (Hoekstra & Kfir, 1997). The fungus was present throughout the growing season and its incidence was high mainly after irrigation or rainfall. However, little attention has been given to microbial pathogens of *C. partellus* in South Africa (Hoekstra and Kfir, 1997). Studies carried out in India, showed that *B. bassiana* could cause up to 60 % mortality to *C. infuscatellus* larvae in sugar-cane (Easwaramoorthy & Santhalakshmi, 1987). Studies in Kenya, using both indigenous and exotic fungi to control *C. partellus* have shown reduction of the larval populations (Maniania, 1993).

Chemical control:

Several insecticides have been screened for the control of maize stem borers in different regions in Africa. Those insecticides which have been found effective as spray or dust treatments include carbofuran, carbaryl, deltamethrin, endosulfan, trichlorfon and synthetic pyrethroids (Van Rensburg and Vandenberg, 1992). However, in Africa, control of stem borers exclusively by insecticides by small-scale farmers is uneconomical and often unpractical (Seshu Reddy, 1998).In India the lower percent damage (4.32%) was observed at the plot sprayed after spinosad 45% EC at 0.5 ml L-1 of water with higher crop yield (4.58 t ha-1) and lowest insect score (1.00) followed by the plot treated with imidacloprid 17.8% @ 0.5 ml L-1 of water with percent damage of 5.55%, crop yield (3.38 t ha-1) and insect sore 1.50(Neupane, 2016). Spray of endsulfan 35 EC @ 280ml/ 100 litres of water at 15 days after germination or Whorl application of carbofuran 3G @ 3-5 granules / whorl 15 days after germination controls the pest. Different treatment modules evaluated against maize stem borer, *C. partellus* at DARS, Budgam Kashmir during *Kharif*, 2015 are as under

Treatment Module Details			
Treatment Module	**Before crop owing**	**15 Days after sowing (15 DAS)**	**30 Days after sowing (30 DAS)**
T_1	Seed treatment with Imidacloprid 48% FS @ 2.4 ml/kg seed	X	X
T_2	Seed treatment with Imidacloprid 48% FS @ 2.4 ml/kg seed	Azadirachtin 0.15 EC @ 2 ml/l of water	X
T_3	Seed treatment with Imidacloprid 48% FS @ 2.4 ml/kg seed	Dimethoate 30 EC @ 1 ml/l of water	X
T_4	Seed treatment with Imidacloprid 48% FS @ 2.4 ml/kg seed	X	Whorl application of Carbofuran 3G @ 10 kg ha^{-1}
T_5	Seed treatment with Imidacloprid 48% FS @ 2.4 ml/kg seed	X	Whorl application of Imidacloprid 0.3% GR @ 10 kg ha^{-1}
T_6	Seed treatment with Imidacloprid 48% FS @ 2.4 ml/kg seed	Azadirachtin 0.15 EC @ 2 ml/l of water	Whorl application of Carbofuran 3G @ 10 kg ha^{-1}
T_7	Seed treatment with Imidacloprid 48% FS @ 2.4 ml/kg seed	Azadirachtin 0.15 EC @ 2 ml/l of water	Whorl application of Imidacloprid 0.3% GR @ 10 kg ha^{-1}
T_8	Seed treatment with Imidacloprid 48% FS @ 2.4 ml/kg seed	Dimethoate 30 EC @ 1 ml/l of water	Whorl application of Carbofuran 3G @ 10 kg ha^{-1}
T_9	Seed treatment with Imidacloprid 48% FS @ 2.4 ml/kg seed	Dimethoate 30 EC @ 1 ml/l of water	Whorl application of Imidacloprid 0.3% GR @ 10 kg ha^{-1}
T_{10}	Untreated (check)		

In module T_7 (comprising seed treatment with imidacloprid 48% FS @ 2.4 ml/kg seed followed by a single spray of *Azadirachtin* 0.15 EC @ 2 ml/litre of water and whorl application of imidacloprid 0.3% GR @ 10 kg $ha^{-1)}$ the leaf infestation was recorded 2.27 per cent 15 days after seed treatment in 18^{th} Standard Week (SW). A single spray of Azadirachtin 0.15 EC 15 days after seed treatment reduced leaf infestation to 2.05 per cent in 19^{th} SW (2^{nd} week of May) which increased to 5.37 per cent during 20^{th} SW (3^{rd} week of May). After 30 days of seed treatment whorl application with imidacloprid 0.3% GR reduced leaf infestation to 2.00 per cent in succeeding week. However, from 21^{st} SW onwards leaf infestation of 2.27 per cent increased up to 7.56 per cent till 27^{th} SW (1^{st} week of July) whereas, in succeeding weeks there was no further increase in leaf infestation and remained static at 7.56 per cent up to 33^{rd} SW (3^{rd} week of August). However, the module T_7 was most effective in recording 83.76 per cent reduction in leaf infestation over control and also had least cumulative mean of 5.61 per cent which was statistically superior to $T_{6,}$ T_3, T_2, T_9, T_4, T_8, T_5, T_1 and untreated check (Hamid, 2015)

Conclusion:

IPM is the most effective control method for controlling maize stem borer and obtaining higher yield of maize grain. So IPM technology should be applied for controlling insect pests and obtaining maximum yield of maize.

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CHAPTER 6
MAIZE WEEVIL (SITOPHILUS ZEAMAIS) AND ITS MANAGEMENT

The maize weevil, *Sitophilus zeamais* Motschulsky (Coleoptera: Curculionidae), is one of the most destructive stored product pests of maize and other cereals as well as other processed and unprocessed stored products. *S. zeamais* causes qualitative and quantitative damage to stored products, with grain weight loss ranging between 20 to 90% for untreated stored maize (Nukenine *et al.,* 2002), and the severity of damage depends on factors which include storage structures and physical and chemical properties of the produce. Heavy infestation of adults and larvae of maize weevil which cause postharvest losses have become increasingly important constraints to storage entomology (Markham *et al,* 1994) and food security. This insect is a primary feeder (major stored pest of Maize) which belongs to order Coleoptera and family Curculionidae. It has been found to infest other types of stored, processed cereal products such as Cassava and various coarse milled grains.

Figure 1: Maize weevil feeding on maize grains

Description:

Scientific Name: *Sitophilus zeamais*

Size:

The maize weevil is similar to the rice weevil, but bigger in size. Very similar in appearance to the Rice Weevil with characteristics described above, except that the insects are longer, adults reaching a length of 3-3.5mm.

Colour:

The reddish markings on the wing covers are more clearly defined.

Description:

The maize weevil is a small snout beetle which varies in size. It varies from dull red-brown to nearly black and is usually marked on the back with four light reddish or yellowish spots. The maize weevil has fully developed wings beneath its wing covers and can fly readily. The thorax is densely pitted with somewhat irregularly shaped punctures, except for a smooth narrow strip extending down the middle of the dorsal (top) side. An egg hatches in a few days into a soft, white, legless, fleshly grub which feeds on the interior of the grain kernel. The grub changes to a naked white pupa and later emerges as an adult beetle. The rate of development is slightly slower for the maize weevil than for the rice weevil. A minimum of thirty days is required for passing through the egg, larval and pupal stages. The maize weevil is slightly larger than the rice weevil and has more distinct colored spots on the forewings. It is a stronger flier than the rice weevil. The habits and life cycle are similar to the rice weevil.

Key Taxonomic characters:

Circular punctures on pronotal dorsum, more than 20 pronotal punctures along the approximate mid line, running from neck to scutellum; Scutellar elevations relatively farther apart compared to their longitudinal length.

Life cycle:

The complete development for the life cycle of this species averages 36 days. The female chews through the surface of the grain, creating a hole. She than deposits a small oval white egg and covers the hole as the ovipositor is removed with a waxy secretion that creates plug. The plug quickly hardens and leaves a small raised area on the seed surface. This provides the only visible evidence that the Kernel is infested. Only one egg is laid inside each grain. When the egg hatches into a white, legless grub, it will remain inside and begin feeding on the grain. The larvae will pupate while inside, than chew a circular exit hole and emerge as an adult beetle. A single female may lay 300 to 400 eggs during her lifetime. Adults can live for 5 to 8 months. Breeding condition requires temperature between 15 and 34 centigrade and 40 % relative humidity. When the adults emerge, the females move to a high surface and release sex pheromones. Males are than attracted to this pheromone.

Host Range:

The Maize weevil commonly attacks standing crops in particular Maize before harvest and is commonly associated with rice .It infests raw or processed cereals such as wheat, oats, Barely, Sorghum, rye and buck wheat. It can breed in crops with a moisture content of a much wider range than *S. oryzae* and has been found in fruit such as apples during storage. Although the Maize weevil cannot readily breed in finely processed grains, it can easily breed in products such as macaroni and noodles and middle cereals that have been exposed to excessive moisture. The significant variation in sizes between adult *S. zeamais* could be a result of the type of food crops used; also female maize weevil has been observed to be bigger than their male counterpart regardless of the food host. *S. zeamais* bred on maize is bigger (4.11 mm long for male and 4.18 mm long for female) than those bred on other cereals, with a relative smallest body size recorded on both rice (3.34 mm long for male and 3.7 mm long for female) and millet (3.45 mm long for male and 3.94 mm long for female). Therefore, kind of food host coupled with the prevailing environmental condition played a significant role in maize weevil body size, as basic nutrients influenced the metabolic activities in insect.

Damage and detection:

Early detection of infestation is difficult. As *S. Zea mays* larvae feed on the interior of individual grains, often leaving only the hulls, flour like grain dust, mixed with frass is evident. Infested grains contain holes through which adults have emerged. A possible indication of infestation is grain, when placed in water floating to the surface. Ragged holes in individual grains, similar to damage caused by the rice weevil and granary weevil, may indicate infestation. In large stores of grain, an increase in temperature may be detected. The most obvious sign of infestation is the emergence of adults .One study recorded, 5 weeks after infestation, the emergence of 100 adults per kg per day.

Figure 2: Emergence of adults from maize grains

Management of Maize weevil:

Prevention is the best strategy to avoid insect problems in stored grains. Proper bin sanitation before introduction of new grain minimizes the need for pesticides. Good sanitation involves the removal of old grain and dust in and around the grain bin. This includes removal of old grain from corners, floors, and walls and grain that may have spilled on the exterior of the bin. Any grain remaining when a bin is emptied can harbor insect infestations which will move into the new grain.

After the bin is cleaned, and all needed repairs have been made, the floor and wall surfaces both inside and outside the bin should be treated. Take special care to treat all cracks, crevices, and areas around doorways and other places where insects could hide or enter. Spray the bins about four to six weeks prior to storing grain.

Before grain is placed in a bin, it should be screened to eliminate fine materials and broken kernels. Grain placed in a clean bin should be checked at two week intervals during warm months and at one month intervals during cooler months for the presence of hotspots, moldy areas, and live insects. If any of these conditions exist, the grain should be aerated to lower the moisture level and temperature. Grain that is to be stored for longer than six months may need a protective application of an approved insecticide. Treatments can be applied as the grain is loaded into the bin through the use of a metering device calibrated to apply the proper amounts. After the grain is binned and leveled, a surface dressing can be applied to prevent insects from entering the grain on the surface. If infestation occurs in spite of these precautions, fumigation of the grain will be necessary. Because of the high toxicity of registered fumigants and technical knowledge needed for their proper use, a qualified pesticide applicator should be contacted to perform the fumigation.

The following treatments are required for effective control:

- Since this pest is temperature tolerant and it will not be effective to kill all adults by freezing. Instead we can store the material in sub zero temperatures for a week or two to have a significant impact.
- Vacuuming of all the closets, shelves, cupboards etc so that eggs can be removed.
  Apply Permethrin with pump sprayers so as to get good coverage quickly of all hatched larvae. Focus should be on baseboards, moldings and floor joints. Since rotencide is one of their favourite foods, be sure to check any bait placements.
- Use of pheromone traps to catch adults.

- The use of Neem seed Kernal extract(NSKE) @2g/kg suppresses the pest infestation.

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Chapter 7
DISEASE MANAGEMENT IN MAIZE

Maize or corn (*Zea mays*) is a plant belonging to the family of grasses (Poaceae). It is cultivated globally being one of the most important cereal crops worldwide. Maize is not only an important human nutrient, but also a basic element of animal feed and raw material for manufacture of many industrial products. However the major maize production areas are located in temperate regions of the globe. The United States, China, Brazil and Mexico account for 70% of global production. India has 5% of corn acreage and contributes 2% of world production. In fact in many countries it is the basic staple food and an important ingredient in the diets of people. Globally, it has been estimated that approximately 21% of the total grain produced is consumed as food. Maize is the third most important food grain in India after wheat and rice. In India, about 28% of maize produced is used for food purpose, about 11% as livestock feed, 48% as poultry feed, 12% in wet milling industry (for example starch and oil production) and 1% as seed.

The decline in production continues through the newer areas are being brought under the cultivation of maize. The intensive cultivation and mono-culturing of maizein maize growing belts together with continual use of diseased material resulted in frequent occurrence of various plant pathogenic diseases. Maize suffers from about 110 diseases on a global basis caused by fungi, bacteria and viruses. The disease spectrum varies in maize under different agro climatic zones. In India 61 diseases of maize recorded so far are considered to constitute the major constraints, limiting production. The major diseases are: four foliar diseases, two pre-flowering and three post-flowering stalk rots, four downy mildews and two sheath diseases. Information on ear, cob and kernel rots, smut and virus diseases are also presented. It has been indicated that diseases in Rabi maize are comparatively lesser than the Kharif maize. It has been reported that about 13.2% of which foliar diseases cause 5 % and stalk rots, root rots and ear rots also contribute 5 % to yield losses (Dhillon and Prasanna, 2001). However, the major diseases of Kashmir and their management practices are described as below:

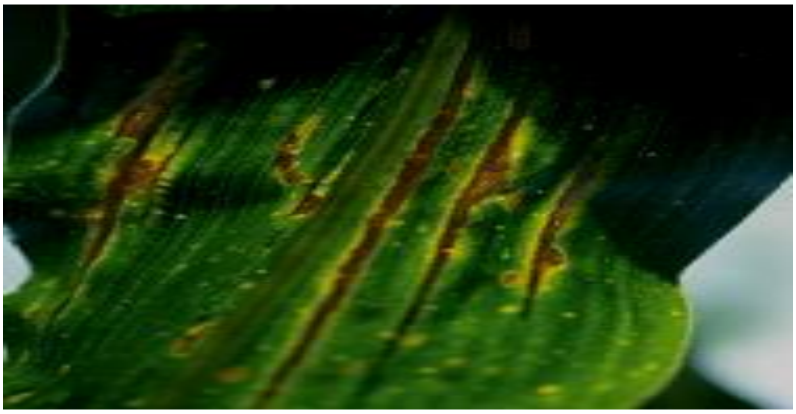
1. Foliar diseases
2. Seed rots and seedling blights
3. Downy mildews
4. Stalk rots and wilts
5. Rust
6. Smuts
7. Cob and ear rots.

Turcicum leaf blight (TLB):

Casual organism: *Helminthosporium turcicum*

Symptoms:

Turcicum leaf blight (Northern corn leaf blight) caused by *Exserohilum turcicum.* It is seen both in Kharif and Rabi seasons. The early symptoms of the disease are oval, water-soaked spots on leaves and the later diseased stage shows characteristic elliptical, grayish green or tan lesions on the leaves measuring 2.5 to 25 cm in length and 4 cm in width. Lesions typically first appear on the lower leaves, increase in size and number until very little living leaf tissue is left. Spores produced on the under surface are arranged in concentric zones resembling a target like pattern when observed against light. Yield losses as high as 70% are attributed to Turcicum leaf blight.



Symptom on leaves

Disease Management:

Cultural Methods:

A) Field Sanitation

- Crop debris is the usual source of primary inoculum. Hence it is imperative to destroy the crop debris either by deep ploughing or burning.
- Avoid excess doses of nitrogen fertilizers
- use of certified disease-free seeds
- crop rotation

B) Chemical management:

Chemical control as general practice is not recommended to the farmers. However, for the protection of precious material, experimental or seed production, spraying with mancozeb @ 0.25 % to 0.40 % (2- 4 applications)made at 10- 15 days interval is effective

B) Use of resistant varieties is the effective method of managing the disease.

Maydis leaf blight (MLB):

Causal organism: *Helminthosporium maydis*

Symptoms:

Leaves show greyish, tan, parallel straight sided or diamond shaped 1-4 cm long, lesions with buff or brown borders or with prominent colour banding or irregular zonation. Symptoms may be confined to leaves or may develop on sheaths, stalks, husks, ears and cobs. The lesions longitudinally elongated typically limited to a single inter vascular region, often coalescing to form more extensive dead portion.

Symptoms on leaves Symptoms on leaf sheath

Disease Management:

Cultural Methods:

Field Sanitation:

- Crop debris is the usual source of primary inoculum. Hence it is imperative to destroy the crop debris either by deep ploughing or burning
- Avoid excess doses of nitrogen fertilizers

Chemical management:

- Use any protective fungicide @ 0.25 to 0.3% of Carbamate or Mancozeb group like mancozeb, zineb, thiram or maneb etc.

Downy mildews (DM):

Casual organism: *Perenosclero sporasorghi, Sclerophthorarayssiae, Sclerophthora macrospore, Peronosclerosporasacchari*

Symptoms:

Downy mildews are an exciting group of fungi which attacks many economically important crop plants. Ten downy mildew diseases are known on maize caused by two genera viz., *Peronosclerospora* and *Sclerophthera*.

Sorghum Downy Mildew (*Perenosclerosporasorghi*):

Systemic interaction, usually localized in late planted areas, malformation of tassels.

Brown Stripe Downy Mildew (*Sclerophthorarayssiae*):

Symptoms observed only on leaves that show chlorotic strips; generally start from top leaves present a burnt appearance in advance stages.

Crazy Top Downy Mildew (*Sclerophthora macrospore*):

Partial or complete malformation of the tassel continues until it resembles a mass of narrow twisted leafy structures; stunted growth of plant.

Sugarcane downy mildew (*Peronosclerosporasacchari*):

Characterized by local lesions that initially are small, round, chlorotic spots and systemic infection which appears as pale yellow to white streaks on leaves. Downy growth on the both leaf surfaces and the plants may be distorted with small, poorly filled ears with mis-shapen tassels.

Downy mildew symptoms on leaves

Management:

Cultural practices:

- For control of downy mildew, the infected plants should be rogued out and destroyed.
- Plant debris should be destroyed by deep ploughing or by burning
- Chemical Management Seed treatment with Metalaxyl at 4 g/kg and foliar spray of mancozeb 2.5 g/l or Metalaxyl MZ at 2g/l is recommended

Brown spot of maize:

Brown spot (*Physoderma maydis*) The disease normally occurs in areas of high rainfall and high mean temperatures.

Casual organism: *Physoderma maydis*

Symptoms:

It attacks leaves, leaf sheaths, stalks, and sometimes outer husks. The first noticeable symptoms develop on leaf blades and consist of small chlorotic spots, arranged as alternate bands of diseased and healthy tissue. Spots on the mid-ribs are circular and dark brown, while lesions on the laminae continue as chlorotic spots. Nodes and internodes also show brown lesions. In severe infections, these may coalesce and induce stalk rotting and lodging.

Symptoms of brown spot of maize on leaf

Management:

As the pathogen is soil borne, field sanitation and seed treatment with protective fungicides is recommended

Common Rust:

This disease is prevalent in cooler parts of the country. It is very common in Himalayan region during kharif season and in South India during rabi season.

Casual organism: *Puccinia sorghi*

Symptoms:

Common Rust (*Puccinia sorghi*) The symptoms are appearance of circular to elongate golden brown or cinnamon brown, powdery, erumpent pustules on both leaf surfaces. As the crop matures brownish black pustules containing dark thick walled two celled teliospores develop. In severe cases infection spreads to sheaths and other plant parts.

Rust pustules on leaf

Management:

Spray with Mancozeb @ 2.5g/lit as soon as first symptoms are observed and spray may be repeated at 10 days interval till flowering.

Smut :

Casual organism: *Ustilago maydis*

Symptoms:

Ground parts of maize plant are susceptible, particularly young, actively growing meristematic tissues. Galls are formed on the ears, auxiliary buds, tassels, stalks and sometimes on the leaves ears, auxiliary buds, tassels, stalks and sometimes on the leaves causes smut disease in ears and tassels by which they are partially transformed to galls. Galls are first covered with a glistening, greenish to silvery white tissue. The interior of these galls darkens and turns into masses of powdery, dark olive brown to black spores, except for galls on leaves. Plants with galls on lower stalks may be barren and produce small ears. Galls on young seedlings may result in stunting or death of the plants.

Deformed inflorescence

Galls on maize leaves

Management:

- Crop rotation if feasible
- Avoiding mechanical injury to plants during cultivation.
- Avoid applying of higher doses of nitrogen.
- Uproot the smut-effected plants.

Chemical management:

Seed treatment with captan 3g/kg of seed

Head Smut:

Casual organism: *Sphacelothecareiliana*

Symptoms:

Head smut appears when ears and tassels are formed. Floral structures may be partially or completely converted to sori containing masses of brownish black teliospores.

Tassel infection may be confined to individual spikelets. In such cases floral bracts grow out in to leafy structures, sometimes in to small shoots. Ears infected plants may be smutted or aborted with leafy buds replacing normal ears. Such plants do not produce pollen. infected plants are dwarf with increased tillering.

Malformed tassel

Aborted leafy bud

Management:

- Crop rotation if possible
- Avoid applying of higher doses of nitrogen.
- Uproot the smut-effected plants.

Chemical management:

- Seed treatment with Captan 3g/kg seed.

Seed Rots and Seedling Disease:

These are incited by species of *Fusarium, Rhizoctonia, Aspergillus, Pythium, Cephalosporium* etc. The problem becomes severe with the use of old seeds stored under high temperature and humidity

Symptoms:

Infected seeds when sown, produce thin stand of the crop with gaps, pre-emergence seed rot, post emergence damping off, brown sunken lesions on mesocotyl, collar rot, wilting, toppling of collapsed of seedlings.

Management:

- Mechanical sieving or winnowing of seed lots meant for sowing eliminates lightweight, chaffy injured or infected seeds.
- Seed should be treated with the fungicide captan 2 to 2.5 g/kg of seed by vigorously shaking in a closed metal drum or earthen vessel before sowing.
- Avoid planting in cold, wet or water logged soil.

CHAPTER 8

STRATEGIES FOR IMPROVING KAREWA SOIL HEALTH FOR PROFITABLE MAIZE CULTIVATION

Maize (*Zea mays* L.) is the most important grain crop especially for dry land areas. Successful maize production depends on the correct application of production inputs that will sustain the environment as well as agricultural production. These inputs are adapted cultivars, plant population, soil tillage, fertilization, weed, insect and disease control, harvesting, marketing and financial resources.

In developed countries, maize is consumed mainly as second-cycle produce, in the form of meat, eggs and dairy products. In developing countries, maize is consumed directly and serves as staple diet for some 200 million people. Most people regard maize as a breakfast cereal.

Maize (*Zea mays*) is the First Ranking Crop in Jammu and Kashmir:

In terms of acreage, maize was the first ranking crop in Jammu and Kashmir in 1994-95. Nearly one-third of the total cropped area was devoted to its cultivation (Fig. 8.3, Table 8.3). It is the staple food of Gujjars and Bakarwals, living in the Kandi and hilly areas. Moreover, the grains form an important cattle food, being fed to farm cattle and horses. The different parts of the plant and the grain are put to a number of industrial uses.

Fertilization of maize:

It is of the utmost importance that the correct soil sampling methods be used when submitting samples for laboratory analysis. Recommended sampling methods to be used are available in the Fertilizer Guidelines for Maize, and can be obtained from: The SKUAST Shalimar recommendations supplied by the Institute should be strictly adhered to, to obtain the required results in the field.

Climate:

- Maize crop is warm weather loving crop and it is grown in wide range of climatic conditions.
- About 85% of the total acreage under maize is grown during monsoon because of the fact that the crop stops growing if night temperature falls below 15.6^0 C or 60^0 F.
- Maize cannot with stand frost at any stage.

- Maize can successfully grown in areas receiving an annual rainfall of 60 cm, which should be well distributed throughout its growing stage.
- Crop needs more than 50% of its total water requirements in about 30 to 35 days after tasseling and inadequate soil moisture at grain filling stage results in a poor yield of shriveled grains.
- Maize needs bright sunny days for its accelerated photosynthetic activity and rapid growth of plants.
- Prolonged cloudy period is harmful for the crop but an intermittent sunlight and cloud of rain is the most ideal for its growth.

Soil:

- Deep fertile soils rich in organic matter and well-drained soils are the most preferred ones however maize can be grown on variety of soils.
- Soil should be medium textured with good water holding capacity.
- Loam or silt loam surface soil and brown silt clay loam having fairly permeable sub soil are the ideal soil types.
- Crop is very sensitive to water logging.
- As the crop is mainly grown in kharif season well drained soils are required.
- The pH should be between 6.5 to 7.5.

Nutrient Management:

- Of the several inputs essential for crop production, the importance of fertilizers is perhaps next only to water, Maize responds well to fertilizers.
- Widespread deficiency of N, P, K and micronutrients like zinc, iron and copper, show the need to apply them for getting optimum yield of maize.
- A crop producing 62.7 quintals grain yield per hectare is estimated to consume 168 Kg N, 57 Kg P205, 135 Kg K20 and 30 Kg Zn.

Integrated nutrient management:

- INM envisaging conjunctive use of chemical fertilizers, organic manures and bio-fertilizers enhances nutrient use efficiency, soil health, crop yields and profitability
- Need to augment supplies of organic manures, fortified, coated & customized fertilizers supplying secondary and micronutrients, bio-fertilizers and soil amendments to have INM on a sound footing.
- Site specific nutrient management.

- These nutrients are to be replenished through balanced fertilizer application and integrated use of nutrients.
- By normal cultivation practices followed by a farmer, all the essential nutrients other than N, P, K and Zn are replenished and maintained.
- Hence there is need to get acquainted with N,P,K and Zn nutrition and their management as they are not replenished in sufficient quantities to produce optimum corn yields.

Organic manures:

- Maize crop requires a regulated and assured supply of nutrients particularly nitrogen throughout its growing period right from seedling stage to grain filling stage.
- A judicious application of organic manure such as well rotten compost or FYM at the rate of 10-15 t/ha about 20 days before sowing the crop is recommended which has been found to be most ideal for an increased crop yields, especially for a grain crop.

Nitrogen:

- Maize plants throughout the season take up nitrogen. Uptake is relatively slow during the first month.
- During the second month it becomes very rapid, if nitrogen is available in the soil.
- Then the uptake slows somewhat, but remains fairly rapid until near maturity. Before grain forms, leaves contain a large proportion of the nitrogen in plant.
- After grain begins to form, much nitrogen is translocated to grain from other parts of plant.
- At maturity about two thirds of the total nitrogen in the above ground parts of the plant should be in grain, with about one third in rest of the plant.
- As nitrogen is needed throughout crop growth and liable for leaching, split application of nitrogen is recommended.
- The nitrogen deficiency at any stage of the growth especially at tasseling and silking stage will leads to virtual crop failure.

Deficiency symptoms:

- In young plants, N deficiency causes the whole plant to be pale, yellowish green and have spindly stalks.
- Yellowing begins on the older, lower leaves and progress up the plant.
- V- shaped yellowing on the tips of the leaves appear later.

Dose:

- 60 kg/ha for *kharif* crop in dryland agriculture system.

Time of application:

- If the crop is grown under dryland condition than entire dose should be given at the time of sowing in furrows.
- If there is possibility of rains than following pattern should be followed:
- 1/2 of nitrogen at sowing.
- 1/4 of nitrogen at knee height stage (35-40 DAS).
- 1/4 of nitrogen at tasseling stage.

Phosphorous:

- Like nitrogen, phosphorus is taken up by maize throughout the season
- At maturity about three fourths of the total phosphorus in the above ground parts of the plant should be in grain.
- All phosphorus is applied at the time of sowing as basal dose.

Deficiency symptoms:

- Usually identified on young plants. Plants are dark green with reddish purple tips and leaf margins.
- Phosphorus deficient plants are smaller, grow more slowly and remain shorter throughout the growing season.

Dosage:

- 40 kg/ha for dry land crop.

Time of application:

Basal placement of phosphate in rows about 5-8 cm deep along seed rows in soil gives the best results as it is less mobile and it does not get lost through leaching.

Potassium:

- The potassium uptake is rapid and most of the uptake is completed before grain formation begins.
- Relatively little potassium is translocated from other plant parts to grain. At maturity the grain should contain not more than one third of the total potassium that is in the above ground parts of the plant.


Shortening of internodes:

- Shortening of internodes.
- Yellowing of leaves and firing at the margins of lower leaves.
- If the deficiency is severe, lower leaves turn yellow but the upper leaves remain green.

Dosage:

There is sufficient amount of available potassium in the soils of maize belt, hence its application should be based on soil test, however, and the crop may be fertilized with 20kg/ha K_2o.

Time of application:

Entire dose of potassium is to be applied as basal dose along with phosphorus at the time of sowing.

Zinc:

- Cultivation of new plant types, leveling of fields and light texture of the soil leads to zinc deficiency thus results in poor grain yields.
- Zinc deficiency symptoms described as 'White bud' in maize.

Deficiency symptoms:

Appears rather early and plants become severely stunted owing to the restricted growth of inter nodes and leaf lamina. Deficient plants show a broad band of bleached tissues on each side of the leaf midrib, beginning from the base.

Correction measures:

- Basal application of zinc sulphate should be given @20 kg/ha
- The deficiency of zinc in plants at later stages of growth , however, may be corrected by foliar application of 5% $ZnSO_4$ dissolved in water with half the quantity of lime (5% of $ZnSO_4$ + 2.5% of hydrated lime).

CHAPTER 9
INTERCROPPING PULSES IN MAIZE (ZEA MAYS L.) FOR EFFICIENT RESOURCE UTILIZATION

Maize (*Zea mays* L.) is the third most important cereal crop next to rice and wheat at global level. It is used as food for human and feed for livestock. It is also used for poultry and piggery to provide energy rich food. Maize is a C_4 plant and an efficient converter of absorbed nutrients into food. It is cultivated on an area of 148.06 m. ha with a production of 706.2 mt and an average productivity of 4769 kg ha^{-1} at global level. In India maize is cultivated on an area of 8.26 million hectare with a production of 19.3 mt. The average yield in India is about 2302 kg/ha (FAI, 2008). In the state of Jammu and Kashmir, it is cultivated over an area of about 0.31 million hectares with a production and productivity level of 0.46 million tonnes and 1.49 tonnes per hectare, respectively. This crop is mostly grown by the tribal people of Kashmir valley on the slopy lands (*Karewas*) where it is subjected to many biotic and abiotic stresses mainly responsible for reduced production and productivity.

However, the production of maize in J & K is very low if compared to that of other maize- growing states. The limited land areas are facing pressure to meet basic demands, especially for food and feed and since most growers own very small and fragmented plots of land as compared to rest of the country. In view of this, there is a need of not only increased production, but also the ability to grow multiple crops in small areas. Therefore, it is need to identify best intercropping system which improves the productivity and resources.

Intercropping as a method of sustainable agriculture is the simultaneous growing of two or more crops during the same season on the same area, which utilize common limiting resources better than the special grown separately as an efficient resource use method.

Intercropping of cereals with legumes has been practiced by the small and medium scale farmers. cowpea, rajmash and mungbean are important legume crops grown in intercropping and is recognized as a common cropping system throughout the Valley due to its advantages for yield increment, weed control, insurance against crop failure, low cost of production and high monetary returns to the farmers, improvement of soil fertility through the addition of nitrogen by fixing and transferring from the legume to the cereal (Ghosh *et al*,, 2006). This indicates that the component crops probably have differing spatial and temporal use of environmental resources such as radiation, water and nutrients.

Pulses are short duration crops and can very well form a component of intercropping and sequence cropping. Being wider spaced, maize crop provides an opportunity for introducing a short duration pulse crop like cowpea, rajmash and mungbean as an intercrop in additive series. Weeds which otherwise would become major production constraint could also be brought under control due to inter cropping. Moreover, such a system also helps in efficient utilization of natural resources (space, moisture and light) to harness maximum productivity. Further, to avoid adverse effect on main crop by addition of intercrop, suitable adjustment in plant population and crop geometry needs to be worked out.

The subsequent harrowing operations have the advantage of a thorough weed control. Firm, seed bed and conservation of moisture in the seed zone which in turn enables early planting and good plant stands is so vital for increasing the productivity in dry lands. In an intercropping system, it is necessary to till or harrow the field immediately after the harvest of one of the component crops as otherwise weeds take over and the yield of longer duration component is drastically reduced.

I. Meaning and scope of intercropping systems:

The cropping system is defined as the combination of crops grown on a given area and time. Intercropping system is a type of mixed cropping and defined as the agricultural practice of cultivating two or more than two crops in the same space at the same time. The common crop combinations in intercropping systems of this region are cereal+legume, particularly maize+cowpea, maize+rajmash, maize+mungbean, maize+beans,. This is a common practice in Kasmir valey, and it is mostly practiced by smallholding famers. The features of an intercropping system differ with soil, climatic condition, economic situation and preferences of the local community.

Much work has been done with cereal-legume intercropping systems and proved its success compared to the monocrops (Alie *et al.,2015,Personal Communication*). One of the most important reasons for smallholder farmers to intercrop is to minimizing the risk against total crop failures and to get different produces to take for his family's food and income. Moreover, intercropping systems more efficiently used the growth factors because they capture more radiation and make better use of the available water and nutrients, reduce pests, diseases incidence and suppress weeds and favour soil-physical conditions, particularly intercropping cereal and legume crops which also maintain and improve soil fertility.

II. Basic principles and practice of maize-legume intercropping:

The success of intercropping system have achieved by various aspects which are need to be taken into consideration before and during the cultivation process. Singh *et al*. (2006) reported that intercropping of legume, particularly black gram with maize has been efficiently utilized the growth resources besides maintaining the soil health. The biggest complementary effects and biggest yield advantages occur when the component crops have different growing periods so make their major demands on resources at different times. Therefore, crops which mature at different times thus separating their periods of maximum demand to nutrients and moisture aerial space and light could be suitably intercropped. For instance, in maize-green gram intercropping system, peak light demand for maize was around 60 days after planting, while green gram was ready to harvest.

A. Suitable Crops:

Selection of the right crop combination is more important in intercropping systems due to the reason that competition of plant could be minimized not only by spatial arrangement, but also by combining those crops which have best able to exploit soil nutrients. Intercropping of cereals and legumes would be valuable because the component crops can utilize different sources of N. The cereal may be more competitive than the legume for soil mineral N, but the legume can fix N symbiotically if effective strains of *Rhizobium* are present in the soil.

B. Time of Sowing:

Effects of the appropriate planting time on the performance of the components under intercrop is a well established fact. Maize planted simultaneously with soybean or before soybean, rajmash or cowpea recorded significantly higher values of leaf area index (LAI), crop growth rate (CGR) and net assimilation rate (NAR), compared to when it was later.

III. Advantages of intercropping:

Efficient Utilization of Resource and Yield Advantage:

The principal advantage of intercropping is the more efficient utilization of the all available resources and the increased productivity compared with each sole crop of the mixture. An alternative to yield for assessing the advantages of intercropping is to use units such as monetary units or nutritional values which may be equally applied to component crops. Yield advantage occurs because growth resources such as light, water, and nutrients are more efficiently absorbed and converted into crop biomass by the intercrop over time and space as a result of differences in competitive ability for growth resources between the component crops, which exploit the variation of the mixed crops in characteristics such as rates of canopy development, final canopy size (width and height), photosynthetic adaptation of canopies to irradiance conditions, and rooting depth.

Regularly intercropped cowpea can help to maintain maize yield to some extent when maize is grown without mineral fertilizers. Intercropping maize with cowpea has been reported to increase light interception in the intercrops, reduce water evaporation, and improve conservation of the soil moisture compared with maize grown alone. In ecological terms, resource complementarity minimizes the niche overlap and the competition between crop species, and allow to crops to capture a greater range of resources than the sole crops. Improved resource use gives in most cases a significant yield advantage, increases the uptake of other nutrients such as N, P, K, and micronutrients, and provides better rooting ability and better cover-up ground as well as higher water use efficiency. Thus, selection of crops that differ in competitive ability in time or space is essential for an efficient intercropping system as well as decisions on when to plant and at what density. Several researches have shown that intercrops are most productive when component crops differ greatly in growth duration. The Land Equivalent Ratio (LER) which shows the efficiency of intercropping for using the environmental resources compared with monocropping with the value of unity to be the critical value and is highest with the quick-maturing pulses. When the Land Equivalent Ratio is greater than one (unity) the intercropping favours the growth and yield of the species, whereas when the Land Equivalent Ratio is lower than one the intercropping negatively affects the growth and yield of the plants grown in mixtures.

Asynchrony in resource demand ensures that the late- maturing crop can recover from possible damage caused by a quick-maturing crop component and the available resources, e.g. radiation capture over time, are used thoroughly until the end of the growing season. Moreover, when the component crops have similar growth durations their peak requirements for growth factor normally occur about the same time and the competition for environments where water stress occurs. Combinations involving crops with slightly differing growth duration, e.g. mixtures of early and late maturing variety of the same species are used in areas with growing seasons of variable-length to exploit the occasional favorable season yet insure against total failure in unfavorable seasons. Differing growing seasons may thus lead to reversals of success in such intercrops, giving more stable yield in intercropping when measured over a run of seasons. If the growing season is long, the late-maturing benefit by abundant resources, whereas if the growing season is short, the early-maturing type can provide a reasonable yield.

Insurance against crop failure:

One important reason for which intercropping is popular is that it is more stable than monocropping. From this point of view, intercropping provides high insurance against crop failure, especially in areas subject to extreme weather conditions such as frost, drought, flood, and overall provides greater financial stability for farmers, making the system particularly suitable for labor-intensive small farms. Thus, if a single crop may often fail because of adverse conditions such as frost, drought, flood, or even pest attack, farmers reduce their risk for total crop failure by growing more than one crop in their small farm. Consequently, intercropping is much less risky than monocropping considering that if one crop of a mixture fails, the component crops may still be harvested. The stability under intercropping can be attributed to the partial restoration of diversity that is lost under monocropping. Moreover, small farmers may be better able to cope with seasonal price variability of commodities which often can destabilize their income.

For example, if the market price may be low favorable for one crop than for others, farmers may be able to benefit from good prices and may suffer less due to poor prices for particular crops, if they grow more crops. Intercropping maize with beans reduced nutrient decline and raised household incomes compared with monocropping of either of the two crops. Combinations involving crops with slightly differing growth duration, e.g. mixtures of early- and late-maturing cultivars of the same species are used in areas with growing seasons of variable-length to exploit the occasional favourable season yet insure against total failure in unfavourable seasons.

Conservation of soil:

Intercropping of cereal with legumes is an excellent practice for reducing soil erosion and sustaining crop production. Where rainfall is excessive, cropping management systems that leave the soil bare for great part of the season may permit excessive soil erosion and runoff, resulting in infertile soils with poor characteristics for crop production. Moreover, deep roots penetrate more breaking up hardpans into the soil and utilize moisture and nutrients from deeper down in the soil. Shallow roots bind the soil particle at the surface and thereby help to reduce erosion. Also, shallow roots help to aerate the soil which increase water holding. Intercropping systems control soil erosion by preventing rain drops from hitting the bare soil where they tend to seal surface pores, prevent water from entering the soil and increase surface runoff. Tall crops act as wind barrier for short crops, in intercrops of tall cereals with short legume crops.

Improvement of Soil Fertility:

Legumes enrich soil by fixing the atmospheric nitrogen converting it from an inorganic form to forms that are available for plants uptake. Biological fixation of atmospheric nitrogen can replace nitrogen fertilization wholly or in part. Biological nitrogen fixation is the major source of nitrogen in legume-cereal mixed cropping systems when nitrogen fertilizer is limited. Moreover, because inorganic fertilizers have much environmental damage such as nitrate pollution, legumes grown in intercropping are regarded as a sustainable and alternative way of introducing N into lower input agro ecosystems. In addition, roots of the legume component can decompose and release nitrogen into the soil where it made available to subsequent crops. Intercropping maize with legumes was far more effective than sole maize to produce higher dry matter yield and roughage for silage with better quality. Also, intercropping common bean with maize in 2 row-replacements improved silage yield and protein content of forage compared with sole crops. The dry matter yield, crude protein yield, and ash content of maize forage increased by intercropping with legumes compared with maize monoculture.

Furthermore, intercropping legumes with maize significantly increased the digestibility of forage. It is evident from the above that intercrops of maize with legumes can substantially increase forage quantity and quality and decrease the requirements for protein supplements compared with maize sole crops. Maize and cowpea intercrops gave higher total forage dry matter digestibility than maize or cowpea sole crops and led to increased forage quality (crude protein and dry matter digestibility concentration) than maize monoculture and higher water-soluble carbohydrate concentrations than sole cowpea.

Atmospheric Nitrogen Fixation (ANF) and Transfer of Nitrogen to Main Crop:

ANF, which enables legumes to depend on atmospheric nitrogen, is important in legume-based cropping systems when fertilizer-Nitrogen is limited, where nitrogen annual depletion was recorded at all levels at rates of 22 kg/ha and mineral-Nitrogen fertilization is neither available nor affordable to smallholder farmers. ANF contributes Nitrogen for legume growth and grain production under different environmental and soil conditions. In addition, the soil may be replenished with Nitrogen by decomposition of legume residues. Legumes species commonly used for provision of grain and green manure have potential to fix between 100 and 300 kg Nitrogen/ha from the atmosphere.

The amount of Nitrogen fixed by the legume component in cereal- legume intercropping systems depends on several factors, such as species, plant morphology, density of component crops, rooting ability, type of management, and competitive abilities of the component crops. Shading did not affect Nitrogen fixation by the component maize crop although incoming light reaching the legume was may be reduced to a large extent. Heavy application of combined N significantly reduces BNF and the soil with a relatively high Nitrogen content (high organic carbon) the mixed cropping yield will increase due to enhanced soil Nitrogen uptake by the maize component, while the cowpea component depends mostly on ANF.

The plant density has little effect on quantity of Nitrogen derived from the nitrogen fixation and the ANF of the legume is not always reduced, but is dependent on the legume's ability to intercept light. Despite the fact that annual fixation rates of 300 kg Nitrogen/ha, the amount measured on farmer's fields are still very low (6 kg Nitrogen/ha to 80 kg Nitrogen/ha).This Nitrogen transfer is considered to occur through root excretion, Nitrogen leached from leaves, leaf fall, and animal excreta if present in the system. The benefits of a legume intercrop with respect to nitrogen are direct transfer of nitrogen from (*Pisum sativum* ssp. *arvense*) resulted in values of Land Equivalent Ratio ranging from 1.05 to 1.24 on a biomass basis and from 1.05 to 1.26 on a protein basis indicating a production advantage of intercropping, known as direct Nitrogen transfer. Despite claims for substantial Nitrogen transfer from grain legumes to the associated cereal crops, the evidence indicate that benefits are limited. Benefits are more likely to occur to subsequent crops as the main transfer path-way is due to root and nodule senescence and fallen leaves. Benefits to associated non-leguminous crop in intercropping systems are influenced by component crop densities, which determine the closeness of legume and non-legume crops, and legume growth stages.

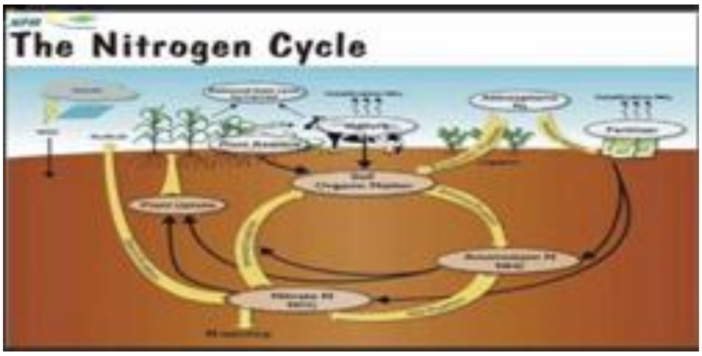


Figure 1: Nitrogen cycle under the atmospheric nitrogen fixation

Promotion of Biodiversity:

Intercropping of compatible plants promotes biodiversity by providing a habitat for a variety of insects and soil organisms that would not be present in a single crop environment. Stable natural systems are typically diverse, containing numerous different kinds of plant species, arthropods, mammals, birds, and microorganisms. As a result, in stable systems, serious pest outbreaks are rare because natural pest control can automatically bring populations back into balance. Therefore, on-farm biodiversity can lead to agro-ecosystems capable of maintaining their own soil fertility, regulating natural protection against pests, and sustaining productivity, from this point of view, crop mixtures which increase farmscape biodiversity can make crop ecosystems more stable and thereby reduce pest incidence problems. Increasing the complexity of the crop environment through intercropping also limits the places where pests can find optimal foraging or reproductive conditions. Intercropping is one way of introducing more biodiversity into agro ecosystems and results from intercropping studies indicate that increased crop diversity may increase the number of ecosystem services provided. Higher species richness may be associated with nutrient cycling characteristics that often can regulate soil fertility, limit nutrient leaching losses, and significantly reduce the negative impacts of pests including that of weeds.

Weed Control:

It is often believed that traditional intercropping systems are better in weeds control compared to the modern monocrops, but it must be known that intercropping is an almost often infinitely complex, and variable system in which adverse effects can also occur. Weed growth basically depends on the competitive ability of the entire crop community, which in intercropping largely depends on the competitive abilities of the component crops and their respective plant populations. Weed control is an important view in intercropping because chemical control is difficult when the crops have emerged. This is also because normally in intercropping a dicotyledonous crop species is combined with a monocotyledonous crop species and therefore the use of herbicides is harmful. In general, intercrops may show weed control advantages over sole crops in two ways. First, suppressing the growth of weeds through allelopathy or greater crop yield and less weed growth may be achieved if intercrops are more effective than sole crops in usurping resources from weeds. Moreover, intercrops may provide yield advantages without suppressing the growth of weeds below levels observed in sole crops if intercrops use resources that are not exploitable by weeds or convert resources into harvestable materials more efficiently than sole crops. Intercropping may often result in reduced weed density and growth compared with sole crops. Intercrops that are effective at suppressing weeds capture a greater share of available resources than sole crops and can be more effective in pre-empting resources by weeds and suppressing weed growth. Intercrops of maize with cowpea intercepted more light, captured greater quantities of macronutrients N, P, and K, produced higher crop yields, and contained lower weed densities and less weed dry matter compared with sole-cropped maize.

Intercropping maize with legumes considerably reduced weed density in the intercrop compared with maize pure stand due to decrease in the available light for weeds in the maize-legume intercrops, which led to a reduction of weed density and weed dry matter compared them with sole crops.

Role in Minimize Pest and Disease Incidence :

An important role of intercropping systems is their ability to reduce the incidence of pests and diseases. However, this is a very complex aspect and both beneficial and detrimental impact has been observed. Infect, sole crops are often more damaged by various pest and disease organisms than when grown as, components of intercrops but the effectiveness of this escape from attack often varies unpredictably.

Crops grown as intercropping enhance the abundance of predators and parasites, which in turn prevent the build-up of pests and disease, thus minimizing the need of using expensive and dangerous chemical insecticides and fungicide. Mixed crop species can also delay the introduction of diseases by reducing the spread of disease carrying spores and by modifying environmental conditions so that they are less favorable to the spread of certain pathogens. The worsening of most insect problems has been associated with the expansion of monocropping at the expense of the natural vegetation, thereby decreasing local habitat diversity.

Changes in environment and host plant quality lead to direct effects on the host plant searching behavior of herbivorous insects as well as indirect effects on their developmental rates and on interactions with natural enemies. Mixed cropping of cowpeas with maize reduced significantly the population density and activity of legume flower bud thrips compared with sole cowpea crop. Similar results were also reported with intercrops of beans, cowpea, and maize, where the reduced pest incidence was attributed to the increased populations of natural enemies favoured by intercropping (Kyamanywa and Tukahirwa, 2008). However, the simultaneous effect on both the environment and the quality may complicate comparisons between systems as several mechanisms can affect herbivorous insects. Black aphid (*Aphis fabae*) infestation of beans was greatly reduced when beans intercropped with older and taller maize plants. There was significantly lower population of insects on the cowpea crop when grown in mixture with maize at specific ratios than in monoculture. Intercropping maize with soybean, and common beans reduced significantly termite attack consequent loss in grain yield of maize compared with maize as sole crop, whereas it increased the predatory ants in maize fields. Also, soybean was more effective in suppressing termite attack than common beans, suggesting the necessity to identify suitable legumes for each intercropping situation.

Intercropping has been shown to be an effective disease management tool. Also, variety mixtures provides functional diversity that limits pathogen and pest expansion due to differential adaptation, i.e. adaptation within races to specific host genotypic backgrounds, which may prevent the rapid evolution of complex pathotypes in mixtures. There are three principles to explain yield of intercrops. The productivity of an attacked crop component may be increased several-fold through intercropping. The influence of attack on the LER is positive where escape occurs, especially if two or more components each escape from their own specific attacker. Use of symptomless carriers of disease can lead to low LER values. Several examples have shown that intercropping can reduce considerably the incidence of various diseases by limiting the spread of carrying spores through certain modification of environmental conditions so that they become less favorable for the spread of certain pathogens. Ascochyta blight (*Mycosphaerella* spp.) severity on cowpea was substantially reduced in cowpea- cereal intercrop compared to the cowpea monocrop when the epidemic was moderate to severe and the disease reduction was partially explained by a modification of the microclimate within the canopy of the intercrop, in particular, a reduction in leaf wetness duration during and after flowering. Climbing genotypes of common beans most susceptible to angular leaf spot (*Phaeoisariopsis griseola*) had less diseased pods in the bean intercrop with maize than in the monocrop and also anthracnose (*Colletotrichum lindemuthianum*) on pods of a susceptible bean cultivar was less intense in the intercrop with maize than in the sole crop.

Intercropping productivity:

Intercropping treatments gave higher cowpea equivalent yield than the sole crop. The One of the most important reasons for intercropping is to ensure that an increased and diverse productivity per unit area is obtained compared to sole cropping.

Economic benefits of cereal-legume intercropping systems:

Intercropping system gave higher cash return to smallholder farmers than growing as the monocrops. Despite the benefits of cereal-legumes intercropping systems in sustainable farming system (SFS), there are some limitation that needs to be solved so as to attain progress. For instance, in some areas of limited phosphorus availability, which is harmful for ANF process and therefore lessen the N contribution of the legume component to system? This is worsened by the current use of mineral fertilizers is still far-low among smallholding farmers, which is associated to accessibility and affordability of appropriate fertilizer. Lack of access to improved seed on time of sowing to these farmers, which is associated to poor market and policy are also contributing negatively to the successful contribution of these systems.

Moreover, legume cover crops and legume trees have been repeatedly demonstrated to improve and maintain soil fertility status under different environmental conditions, compared to grain legumes intercropping systems. However, they have increasingly emerged as the least prioritized by smallholder farmers under their prevailing condition, which can be largely attributed to their lack of short-term benefits of both food and income. Furthermore, there is lack of information and knowledge about fertility management technologies because most of the research that has been done related to cereal-legumes intercropping system in the past decades had less involvement of farmers, particularly the resource-constrained farmers, which is worsened by low know how of extension services on legume-based ISFS technologies. Consequently, there are misconceptions among smallholder farmers about the role of legumes in the soil fertility management.

Conclusion:

Research on maize-legume intercropping systems has shown advantage in both soil fertility and crop yields, particularly for cereal crop which is the staple food crop for smallholder farmers, beside its other advantage for soil conservation, minimizing incidence of pest and disease and insurance against crop failure,. However, lack of participatory approaches and fragmentation of land under farmer's conditions, mainly the inclusion of resource-less farmers, could not allow easy adoption by these smallholders. Therefore, it is necessary more research that involves smallholder farmers for sustainable production and productivity. Also, there is need for proper handle of several issues of accessibility and affordability of improving economic status of smallholder farmer.

CHAPTER 10

PROSPECTS OF FORAGE MAIZE IN KASHMIR

Agriculture and animal husbandry in India are interwoven with the intricate fabric ofthe society in cultural, religious and economical ways as mixed farming and livestockrearing forms an integral part of rural living. Although the contribution of agriculturalsector in the Indian economy is steadily declining (from 36.4% in 1982-83 to 18.5%in 2006-07), the agriculture and livestock sector still provides employment to 52% ofthe work force.

Livestock provides draught power, rural transport, manure, fuel, milk and meat.Most often, livestock is the only source of cash income for subsistence farms and alsoserves as insurance in the event of crop failure. Further, global energy crisis will leadto utilization of livestock-based bioenergy as well as waste recycling for organic manureand organic forage production for quality animal products.India supports nearly 20% of the world livestock and 16.8% human population ona land area of only 2.3%. It is leader in cattle (16%) and buffalo (55%) population andhas world’s second largest goat (20%) and fourth largest sheep (5%) population.The agricultural production systems in India are based upon mixed farming in which twomajor enterprises are crops and livestock. Farmers mix these two enterprises to diversify the useof their resources for maximizing family income. Livestock production is the backbone of Indianagriculture contributing 7% to National GDP and a source of employment and ultimate livelihoodfor 70% of the population in rural areas. The human population in India is expected to reachover 1,400 million by 2025. The 27.8% urban population is poised to increase by over 58% by2025. Urbanization has brought a marked shift in the lifestyle of people in feeding habits towardsmilk products, meat and eggs with resultant increase in the demand for livestock products.

Periurban livestock farming is an indicator of fast changing economic scenario in livestock sector.Livestock population is around 500 million and is expected to grow at the rate of 1.23% in thecoming years (Table 1). The milk production in India is 94.5 million tones, the highest in theworld. The per capita milk availability in the country is 240 g/day which fulfills the minimumrequirement of 220 g/day as suggested by Nutritional Advisory Committee of the Indian Councilof Medical Research (ICMR). The milk production to a large extent depends upon the availabilityof good quality fodder.The 17th Livestock Census (2003) has placed the total livestock population at 485million and that of poultry birds at 489 million. Total population is expected to grow at1.23% in the coming years. The livestock population in terms of million adult cattle units is presented in Table 1.

To meet out the needs of the ever increasing livestock population the production as well productivity of fodder is to be increased. However, the increasing cultivation of cereal and cash crops has, in fact, contributed towards a decline in the area under fodder cultivation. Therefore, there is a tremendous pressure of livestock on available total feed and fodder, as land available for fodder production has been decreasing. At present, the country faces a net deficit of 61.1%green fodder, 21.9% dry crop residues and 64% concentrate feeds. Supply and demand scenario of forage and roughage is presented in Table 2. To meet the current level of livestock production and its annual growth in population, the deficit in all components of fodder, dry crop residues and feed has to be met from either increasing productivity, utilizing untapped feed resources, increasing land area (not possible due to human pressure for food crops) or through the adoption of some innovative strategies increasing land area (not possible due to human pressure for food crops) or through the adoption of some innovative strategies. For fodder production has been decreasing. At present, the country faces a net deficit of 61.1%green fodder, 21.9% dry crop residues and 64% concentrate feeds. Supply and demand scenario of forage and roughage is presented in Table 2. To meet the current level of livestock production and its annual growth in population, the deficit in all components of fodder, dry crop residues and feed has to be met from either increasing productivity, utilizing untapped feed resources, increasing land area (not possible due to human pressure for food crops) or through the adoption of some innovative strategies.

Table 1: Livestock population in terms of million adult cattle units

Year	Cattle	Buffalo	Goat	Sheep	Equine	Camel	total
1995	180.5	82.2	9.2	4.0	0.5	0.9	278.0
2000	187.1	87.7	9.9	4.1	0.4	1.0	290.0
2005	192.2	92.6	10.5	4.2	0.3	1.0	301.0
2010	197.3	97.5	11.2	4.3	0.3	1.0	312.0
2015	202.3	102.4	11.8	4.4	0.1	1.1	322.0
2020	207.4	107.3	12.5	4.5	0.1	1.1	333.0
2025	212.5	112.2	13.2	4.6	0.1	1.1	344.0

(Source: Based on X Five Year Plan Document, Government of India)

The demand will reach to 1,170 million tonnes of green fodder and 650 million tonnes of dry forage and 152 million tonnes of concentrate feed in 2025. At the current level of growth in forage resources, there will be 65% deficit in green fodder and 25% deficit in dry fodder. Green forage supply situation has to grow at 3.2% to meet the projected demand.

Dry roughage is vastly used as fodder throughout the country. Almost all the wheat straw produced in the northwestern plain zone is utilized as animal fodder mainly in the dyer regions such as Rajasthan, Madhya Pradesh, some pockets of Haryana and eastern Uttar Pradesh. A significant segment of paddy straw is also utilized as animal fodder particularly in the middle as well southern India. The nutritional quality of roughages is very poor. Although, wheat straw provides some cellulosic carbohydrates and could be utilized along with green forages as well as concentrates, but the practice of using rice straw as fodder is totally unrealistic as nothing nutritious comes out of paddy straw. Moreover, it may contain deleterious amounts of selenium which may cause life threatening toxicity to the cattle.

Table 2: Supply and demand scenario of forage and roughages (1995 - 2025) (in million tonnes)

Year	Supply		Demand		Deficit as% of demand (as actual)	
	Green	Dry	Green	Dry	Green	Dry
1995	379.3	421	947	526	568 (59.95)	105 (19.95)
2000	384.5	428	988	549	604 (61.10)	121 (21.93)
2005	389.9	443	1,025	569	635 (61.96)	126 (22.08)
2010	395.2	451	1,061	589	666 (62.76)	138 (23.46)
2015	400.6	466	1,097	609	696 (63.50)	143 (23.56)
2020	405.9	473	1,134	630	728(64.21)	157 (24.81)
2025	411.3	488	1,170	650	759 (64.87)	162 (24.92)

(Source: Based on X Five Year Plan Document, Government of India. Figures in parentheses indicate the deficit in percentage)

Green forages are rich and cheapest source of carbohydrates, protein, vitamins and minerals for dairy animals. The importance of forages in our country is well recognized since feeding forages alone accounts for over 60% of the cost of milk production. Hence by providing sufficient quantities of fodder instead of costly concentrates and feeds to the milch animals, the cost of milk production can considerably be reduced. However, the practice of growing cultivated green forages for cattle feeding is limited to particular area of northwestern plain zones comprising of Punjab, Haryana and western Utter Pradesh. The farmers in the rest of the country mainly depend upon grasslands/pastures, forests, straws and stovers for feeding their cattle.

Although the genetic potential contributes significantly towards higher milk production but the genetic potential of high yielding animals can be realized only if they are fed well with quality fodder. Forages are rich source of protein (8-10 % in non-legumes and 18-22 % in legumes), vitamins (vitamin A-carotene), minerals (Ca - 1.5 to 3.0 % in legumes and 0.3 to 1.3 % in non-legumes; P - 0.28 to 0.65 % in legumes and 0.12 to 0.30 % in non-legumes), carbohydrates, micronutrients and having *in vitro* dry matter digestibility (IVDMD) between 55 to 75%.This is perhaps the major reason behind poor productivity of Indian buffaloes as well cows. These nutrients are essential for growth, maintenance, reproduction and milk production of the animals. The feeding cost of milk production can considerably be reduced by substituting high quality forages for concentrate. Moreover, the nutrients from the fodders are easily digestible as compared to the nutrients form concentrates. The lush green forages are palatable and are liked by the animals very much to fill their stomach to satisfy the hunger. For full exploitation of milk production of dairy animals, it is imperative that nutritious lush green fodder is made available at the rate of 40-50 kg per adult animal per day throughout the year. To feed this livestock population, we have to design some innovative strategies so that the produce from agriculture could effectively be utilized for livestock feeding.

Maize the solution provider:

Maize crop has an important place in the food grain basket of our country and is the third most important versatile food grain crop due to its importance in food, feed, specialty corn, starch etc. The last few years have seen dramatic changes in the production and productivity of maize. The adoption of single cross maize the 4 per cent growth rate for agriculture in general and4.7 per cent for maize in particular as the target set by Planning Commission. As per the latest estimates of Ministry of Agriculture, Government of India, the maize productivity is heading towards a record output of 21.28 mt of maize this year as against 16.72 mt produced last year. As a result India became importer to exporter of maize and consequently, maize has occupied an important position in the food stocks of the country. Considering changing climatic scenario and impact of single cross maize hybrid, it is estimated that production and productivity of maize is going to rise further. Maize in India, contributes nearly 9 % in the National food basket and more than Rs. 100 billion to the agricultural GDP at current prices apart from the generating employment to over 100 million man-days at the farm and downstream agricultural and industrial sectors. The consumption pattern for maize produced in India at present includes poultry feed 52 percent, human food 24 per cent, animal feed 11 per cent and more than 22 per cent going towards industrial processing. With the growing demand of poultry feed the demand for maize is also going up in the country. It is the crop with the highest per day productivity. Some estimates indicate that India may have to produce 55 million tonnes of maize to meet its requirement for human consumption, poultry, piggery, pharma industry and fodder by 2030.

Maize is one of the most versatile emerging crops having wider adaptability under varied agro-climatic conditions. As it has yield potential far higher than any other cereal, it is sometimes referred to as the miracle crop or the 'Queen of Cereals'. The United States of America (USA) is the largest producer of maize and contributes nearly 35 % of the total production in the world and maize is the driver of the US economy. The USA has the highest productivity (> 9.6 t/ha) which is double than the global average (4.92 t/ha). Whereas, the average productivity in India is 2.43 t ha-1.

Maize is native of America. It was introduced to India by Portuguese during 17th century. Its cultivation in India dates back to the Maratha Empire. Maize is normally a monoecious plant having two types of inflorescence, the female inflorescence develops into cobs and the male inflorescence contains the male flowers. The inflorescence is born on the top of the stem and the female flowers are born inside the young cobs which spring from one of the nodes located at the middle of the stem. Maize is a warm weather plant. It grows from sea level to 3000 meters altitude. It can be grown under diverse climatic conditions also. It is grown in many parts of the country throughout the year. Kharif (monsoon) season is the main growing season in northern India. In the South, however, maize may be sown any time from April to October, as climate is warm even in the winter season. Maize requires considerable moisture and warmth from germination to flowering. The most suitable temperature for germination is 21°C and for growth32°C. Extremely high temperature and low humidity during flowering damage the foliage, desiccate the pollen and interfere with proper pollination, resulting in poor grain formation. About 50 to 75 cm of well distributed rain, is conducive to proper growth. Maize is very sensitive to stagnant water, particularly during its early stages of growth.

Maize has been classified into several groups or types based on the endosperm of the kernels. These are described as under:

1. Dent corn (*Zea mays indentata*):

It is popularly known as dent corn because of dent formation on the top of the kernel having yellow or white colour. The depression or dent in the crown of the seed is the result of rapid drying and shrinkage of the soft starch. This type is extensively grown in the U.S.A.

2. Flint corn (*Zea mays indurata*):

This is the type first developed by Europeans. It has an early maturity. Kernels of this typeare rounded on the top. It is grown in Europe, Asia, Central America and South America. It is aprinciple type of grain corn grown in India.

3. Pop corn (*Zea mays everta*):

Its cultivation is mainly confined to the new world. It has small kernels with hard corneous endosperm. The grains are used for human consumption and the basis of pop corn confections.

4. Flour corn (*Zea mays amylacea*):

It resembles flint corn in appearance and ear characteristics. The grains are composed of soft starch and have little or no dent. Flour corn is one of the oldest types of maize grown widely in the U.S.A. and South Africa.

5. Sweet corn (*Zea mays saccharata*):

The sugar and starch make the major component of the endosperm that result in the sweetish taste of kernels before they attain the maturity and after maturity the kernels become wrinkled. Nowadays the crop is widely cultivated in the peri-urban regions of the country. The cobs are picked up green for canning and table purpose.

6. Waxy corn (*Zea mays certain)*:

The Kernels look to have waxy appearance with gummy starch because of higher amylopectin (upto 100%) whereas common maize starch is about 70 per cent of amylopectin. Its origin is supposed to be in China but many waxy hybrids developed in the U.S.A. are producing starch similar to that of tapioca and are grown commercially.

7. Baby corn:

Baby corn is the young ear of female inflorescence of maize plant harvested before fertilization when the silk has just emerged. In the changing socio-economic scenario, the cultivation of baby corn and sweet corn are rapidly increasing particularly in the peri-urban regions of the country. Due to proximity to big cities, baby corn and sweet corn are widely cultivated and subsequently sold at reasonable prices in the market. Farmers nowadays are growing 3-4 crops of these specialty corns a year. Baby corn and sweet corn products are attracting the fancy of rich and upper middle class and are commonly available in the hotels, restaurants, malls etc. Due to the increasing cultivation of these corns, a lot of maize stalks are also available which could efficiently be used as animal fodder. This is an area where maize can play an important role as animal fodder. Apart from furnishing the nutritional needs of the mankind maize could also fulfill the nutritional requirement of livestock. The baby corn maize stalks are green, succulent, nutritious and possess excellent digestibility.

Fodder quality:

Forage quality is defined in various ways but is often poorly understood. It represents a simple concept, yet encompasses much complexity. Though important, forage quality often receives far less consideration than it deserves. Adequate animal nutrition is essential for high rates of gain, ample milk production, efficient reproduction, and for adequate profits. However, forage quality varies greatly among and within forage crops, and nutritional needs vary among and within animal species and classes. Producing suitable quality forage for a given situation requires knowing the factors that affect forage quality, then exercising management accordingly. Analyzing forages for nutrient content can be used to determine whether quality is adequate and to guide proper ration supplementation. In recent years, advances in plant and animal breeding, introduction of new products, and development of new management approaches have made it possible to increase animal performance. However, for this to be realized there must be additional focus on forage quality.

Forage quality can be defined as the extent to which forage has the potential to produce a desired animal response. Factors that influence forage quality include the following:

Palatability:

Will the animals eat the forage?

Animals select one forage over another based on smell, feel, and taste. Palatability may therefore be influenced by texture, leafiness, fertilization, moisture content, pest infestation, or compounds that cause forage to taste sweet, sour, or salty. High-quality forages are generally highly palatable.

Intake:

How much will they eat?

Animals must consume adequate quantities of forage to perform well. Typically, the higher the palatability and forage quality, the higher the intake.

Digestibility:

How much of the forage will be digested?

Digestibility (the extent to which forages absorbed as it passes through an animal's digestive tract) varies greatly. Immature, leafyplant tissues may be 80 to 90% digested, while less than 50% of mature, stemmy material is digested.

Nutrient content:

Once digested, will the forage provide an adequate level of nutrients?

Livingforage plants usually contain 70 to 90% water. To standardize analyses, forage yield andnutrient content are usually expressed on a dry matter (DM) basis. The forages are analyzedby two systems of analysis (i) Proximate analysis of forages and (ii) Van Soest system

Anti-quality factors:

Various compounds may be present in forages that can lower animal performance, cause sickness, or even result in death. Such compounds include tannins, nitrates, alkaloids, cyanoglycosides, oxalates, estrogens, and mycotoxins. The presence and/or severity of these elements depend on the plant species present (including weeds), time of year, environmental conditions, and animal sensitivity. High-quality forages must not containharmful levels of anti-quality components.

Animal performance:

Is the ultimate test of forage quality, especially when forages are fedalone and free choice. Forage quality encompasses "nutritive value" (the potential forsupplying nutrients, i.e., digestibility and nutrient content), how much animals will consume and any anti-quality factors present. Animal performance can be influenced by any of severalfactors associated with either the plants or the animals. Failure to give proper considerationto any of these factors may reduce an animal's performance level, which in turn reducespotential income.

Factors affecting forage quality:

Many factors influence forage quality. The most important are forage species, stage ofmaturity at harvest, and (for stored forages) harvesting and storage methods. Secondary factors include soil fertility and fertilization, temperatures during forage growth, and the most important is variety.

1. Species difference:

Legume vs grasses:

Legumes generally produces higher quality forage than grasses. This is because that legumesusually have less fiber grasses and favor higher intake than grasses. One of the most significantbenefit of growing legumes with grasses is improvement of forage quality. Examples include: growing maize with cowpea, bajra with guar, berseem with ryegrass and berseem with oats etc.

2. Maturity Stage:

Maturity stage at harvest is one of the most important factors determining forage quality ofa given species. Forage quality declines with advancing maturity. For examples maize exhibitsideal forage quality when the grains are in the milk stage, afterwards the quality keeps on declining.Maturity at harvest also influence forage consumption by animals. As plant matures and becomemore fibrous, forage intake drops drastically. Intake potential decreases and NDF concentrationincreases as plant grow. This is because NDF is more difficult to digest than the non-fibercomponents of forage. Also the rate at which forage is digested slows as plant tem ratio is a major cause of concern of the decline in forage quality withmaturity, and also the loss in quality that occurs under adverse hay curing conditions. Leaves arehigher in quality than stems, and the proportion of leaves in forage decline as the plant matures

3. Fertilization:

Fertilization of grasses with nitrogen (N) often substantially increases yield and also generallyincreases CP levels in the forage. However excess fertilization may contribute towardsaccumulation of nitrates in forages which is a potent anti-nutritional component and may causelarge scale livestock losses. Therefore the recommended dose of fertilization should be applied.Fertilization usually has little or no effect on digestibility. Fertilization with phosphorus (P), potassium (K), or other nutrients that increase yield may actually slightly reduce forage qualitywhen growth is rapid. Excessive levels of some elements such as potassium may in some casesdecrease the availability of other elements such as magnesium (Mg) in the diet.

4. Daily fluctuations in forage quality:

As early as the 1940s, changes in soluble carbohydrate levels in alfalfa were linked to timeof day. Plants accumulate soluble carbohydrates during daylight and then use them overnight.Thus, soluble sugars are lowest in the morning and highest after a day of bright sunshine. Recentstudies in low rainfall climates have shown higher forage quality when lucerne is harvested inthe late afternoon rather than in the morning. It appears that the advantage of afternoon harvestis greatest on cool, sunny days and when the forage is highly conditioned to increase drying ratesand minimize respiration in the windrow. However, afternoon harvests may not be advisable inhigh rainfall areas.

Maize as fodder:

Maize is an excellent crop in terms of biomass production. Since the production as well asproductivity of maize is increasing in our country the availability of biomass from maize is alsoincreasing by the same magnitude. Maize straw is used as animal fodder since the ancient times. However, the fodder quality of green maize is far excellent. Amongst the non-legume cultivatedfodders, maize is the only fodder which produces better nutritional quality along with goodquantity of biomass. It is commonly grown as a summer fodder in the northwestern regions ofthe country particularly Punjab, Haryana and Western Uttar Pradesh. Its quality is much betterthan sorghum and pearl millet since both sorghum as well as pearl millet possesses anti-qualitycomponents such as HCN and oxalate, respectively. Secondly baby corn is ready for harvestapproximately 2 months after sowing. This means the baby corn as well as maize fodder is availablein bulk approximately 2 months after sowing the crop. The nutritional quality of maize is comparedwith other non-legume fodders in the following Table 3.

Crude protein and *in-vitro* dry matter digestibility (IVDMD) are two important nutritionalquality parameters governing fodder quality. Both crude protein as well IVDMD in maizeare highest among the othercompetitive fodders. The biomass production of maize is also equivalent to sorghum and pearl millet. Pearl millet is ahardy crop and cultivated in thedryer regions of the country, whereas, sorghum though cultivated throughout the country, but contains the mosttoxic anti-quality component called prussic acid (HCN). The toxicity of HCN is so severe that the animal dies within minutes after consuming young sorghum crop.

The HCN content is higher in the young crop compared to mature plant. It is, therefore, recommended that only mature sorghum should be fed to the animals. The maize on the other hand is almost free from any anti-quality components.

Table 3: Comparative nutritional quality of non-legume fodders

Fodder crop	Physiological stage	Harvesting stage (DAS)	CP (%)	IVDMD (%)
Maize	Silk to milk stage	55-65	11-8	68-52
Bajra	Boot stage	45-55	10-7	62-55
Sorghum	Initiation of flowering	70-80	8-7	60-57
Teosinte	Pre-flowering	80-85	9-7	62-58
Sudax	Subsequent cutting after 30 days	65-70	11-7	60-55
Napier bajra hybrid	One metre height and subsequent cutting after 30 days	55-60	11-7	60-55
Guinea grass	One metre height and subsequent cutting after 25-30 days	55-60	10-8	60-57

(Source: Gupta et al., 2004)

Silage making:

For dairying to be successful there must be year-round fodder supply. In India farmers are routinely faced with an acute shortage of green fodder twice a year particularly during the monthsof Nov-Dec and May-June, called the lean periods. During this period, the farmers have to feed straws and stovers along with the costly concentrates to fulfill the daily dietary requirements ofcattle. The straws or stovers are not nutritious feed and is often deficient in some vital nutrients andhence reduce the milk production potential of the cattle, whereas the concentrates are economically not viable. Therefore, it is important to produce and conserve forages in sufficient quantity and ofgood enough quality. Conserved forage is needed to maintain milk production over the dry monthsas well as put the cow into good condition so that she will conceive within four months after shecalved and thus have a calf every year.

How maize should be conserved for the dry season: silage?

Maize can be conserved as silage. It has to have 30% dry matter to be ensiled successfully. There is no need to try and dry out the plant material any more than that, so wet weather is notsuch a constraint as it is with making hay. This means the crop can be cut any time, depending onwhen it was planted.

What is silage?

Silage is the product from a series ofprocesses by which cut forage of highmoisture content is fermented to produce astable feed which resists further breakdownin anaerobic storage. The objective is to retainor augment the nutrients present in theoriginal forage and deliver a silage acceptedby livestock; this is usually attained throughlactic acid bacterial. A good silage make fromtropical forages has a pH less than 5.0, thepercent of total nitrogen which is ammonia (NH3N:N) of less than 15%, lactic acid whichis 50% or more of the total organic acids andbutyric acid content of not greater than 0.5%of the total dry matter.When forage is putinto a sealed container such as a pit coveredwith plastic, a drum or a plastic bag, thecontainer is called a silo. A silo has to becompletely sealed against air and the forage material must be chopped and compressed in the siloto ensure the fast development of anaerobic conditions and a rapid fall in pH. In these conditions, lactic acid bacteria, which convert some of the sugars in the plant into the pleasant tasting lacticacid, prevail over undesirable bacterial such as clostridia which produce butyric acid, which isunpalatable to livestock, and moulds, which cause rotting of the silage. A good silage has a sweetsmell and cattle, goats and sheep will readily eat it. Silage can be made quite cheaply and easily, provided it is done correctly.

Maize stover:

Maize stover consists of the leaves and stalks of maize plants left in a field after harvest andconsists of the residue: stalk; the leaf, husk, and cob remaining in the field following the harvest ofcereal grain. It makes up about half of the yield of a crop. Maize stover is a very common agriculturalproduct in areas having large acreage under maize cultivation. The stover can also contain otherweeds and grasses the non-grain part of harvested corn and has low water content and is verybulky.Stover is widely used as the major source of animal feed in our country particularly in theregions having plenty of maize production. With the increasing production and productivity of maize, the maize stover is available in plenty. Corn grain accounts for about 45% of the total drymatter yield of a corn field. Corn stover amounts would range from 3 to 4 tons per acre. The ratio of corn stover to grain is typically assumed to be 1:1; thus, there is 40 quintals of maize stover produced for every 40 quintals of grain harvested. Thus, stover production estimates are typically based on grain harvest figures (this assumes ~ 12-15 per cent moisture). In our country the currenttechnology of maize harvest is suitable for the 100% availability of stover. Unlike in wheat, wherecombine harvest is unsuitable for the harvest of straw and most of the straw is burnt in the fieldsparticularly in the northwestern regions of Punjab and Haryana, the maize is harvested manually and the stover is collected.

Maize stover is utilized for animal feeding during the scarcity of greenfodder called lean periods. In the northwestern plan regions farmers are often faced with scarcityof green fodder during the months of May-June and again during November-December. Duringthis period wheat straw as well maize stovers are the principle sources of fodder. Stover is stored inlarge heaps to be used during lean periods. Due to scarcity of fodder stover is often sold at exorbitantrates ranging from Rs. 1-5 per kg. Maize stover is often transported from maize growing areas todryer regions of the country and there exists a good business as stover market is flourishing everyyear. Maize stover can successfully be incorporated in ruminant rations and that such rations have relatively high digestibility.

Thus it could be concluded that maize is an excellent crop which could effectively be utilizedas a feed and fodder crop. Specialty corn is going to play an important role in the socio economicperspective of the rural folk. Baby corn and sweet corn cultivation will substantially add up to theincome of the farmers as specialty corn is sold at reasonably good price in the market, where thegreen fodder will boost the dairy industry. The silage making is breakthrough technology whichcould provide a quantum boost to the dairy sector. And lastly the urea treatment of maize stover is a simple technique much suitable for small and marginal farmers, whereby then can easily enhancethe milk production potential of their cattle. In the state of Jammu and Kashmir total cultivable area under fodder production is 55.35 thousand hectares of which 26.18, 23.62 and 5.58 thousand hectares falls under Jammu, Kashmir and Ladakh regions (Anonymous, 2008). The total livestock population in Jammu and Kashmir comprising of cattle, buffaloes, sheep, horses, donkeys, goats, camels and yaks is 93.0 lac (Anonymous, 2008). The availability and requirement of green fodder in Kashmir division during the year 2008-09 was 2096 and 6536 thousand tonnes respectively, thereby resulting in a fodder deficit of 67.93 per cent. In view of annual increase in livestock population, the projected availability, requirement and deficit in green fodders by 2020 would be 2200.8 and 6732.0 thousand tonnes and 67.32 per cent, respectively, (Anonymous, 2008). The solution therefore, lies in maximizing fodder production in space and time, identifying new forage resources, increasing production with existing farming systems and utilizing marginal, sub-marginal lands and problem soils for developing fodder resources. Maize is widely cultivated in Jammu and Kashmir, being grown in the Kandi, Karewa, and plain areas .It thrives well in the sandy loam to loamy soils. Varieties of maize have also been developed which perform well in the colder hilly and mountainous areas. It can be grown in all such regions where the summer is long enough to permit its cultivation, and frost does not set in too early. It needs about 30°C temperature at the time of germination, growth and development, and over 20°C at the time of ripening. Keeping the national scenario in view Kashmir also has a great potential for growing maize as a dual purpose crop. In order to meet the growing demand of fodder for the increasing livestock population which in turn will cater the need of ever increasing human population some maize varieties recommended mainly for forage purpose are: African tall; some baby corn varieties.

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CHAPTER 11
MANAGEMENT OF TURCICUM LEAF BLIGHT OF MAIZE

Northern leaf blight of maize also called as Turcicum leaf blight is incited by the fungus *Exserohilum turcicum* (Pass.) teleomorph, *Setosphaeria turcica* (Luttrell) K. J. Leonard and E. G. Suggs. The disease is widely spread and economically most important disease of maize in the world (Chung *et al*., 2010; Sibiya *et al*., 2013). The disease causes enormous damage to crop and the loss in grain yield ranges from 24 to 91 per cent (Pant *et al*., 2000; Nwanosike *et al*., 2015). The damage to maize crop can be manifold if the disease develops prior to silk emergence. The disease epidemics at an early stage cause premature death of blighted leaves thereby reduce the photosynthetic capacity of the maize plants during the critical stage of grain filling besides the fodder quality is lost, which is of great value under temperate agro climatic conditions as the same is being fed to the cattle during lean season (Payak and Renfro, 1968). Northern leaf blight of maize is a constraint to global maize production. It is an ubiquitous foliar disease of maize in many temperate and tropical environments which can cause yield losses up of to 70% (Yeshitila, 2003). Apart from yield loss, the disease causes qualitative changes in the seed resulting in decreased sugar content, germination capacity and severely infected plants are predisposed to stalk rot (Cardwell *et al*., 1997).

Northern leaf blight has worldwide distribution particularly in areas where high humidity (75-90 per cent) and moderate temperature (22-25^{o}C) prevails during the cropping season (Gregory, 2004). Disease is most prevalent in all the major maize growing regions of India during rainy (Kharif) as well as winter (Rabi) season (Lal, 1991). This disease has also been observed to be the most important limiting factor for maize production in the hills. Turcicum leaf blight is of particular concern in the tropical highlands, where conditions favour disease development. The disease was also found to be the major constraint of maize production under temperate agro-ecologies of Jammu and Kashmir (Ahangar *et al*., 2016).

Symptoms:

The disease starts at first as small, oval, greyish green and water soaked spots which grow into elongated, spindle-shaped necrotic lesions (Chenulu and Hora, 1962). They appear first on lower leaves and the number of spots increases with the development of plant, leads to complete blighting of the foliage thereby reducing the amount of leaf surface area available for photosynthesis (Fig.-1). Northern Leaf blight lesions are elongated elliptical greyish lesions, measuring up to 12 mm wide and 2.5-15 cm long which run parallel to leaf margin (De Rossi *et al*., 2015).

Initial symptoms	**Elongated elliptical greyish lesions**	**Blighting of the foliage**

Factors responsible:

Susceptibility of maize varieties: Maize varieties vary in their resistance against Northern leaf blight. Selection of proper maize variety based on disease reaction is an important step in managing the disease. Continuous maize cultivation favours development of Northern leaf blight. The fungus *E. turcicum* overwinter on infected corn leaves. Fields with heavy maize residue will be at the most risk for severe disease outbreak. Minimum tillage fields are at threat because of the residue remaining on the soil surface.

Plant age has been implicated in contributing to the onset and severity of the disease. The infection of *Exserohilum turcicum* on maize occurs from seedling to harvesting. However, maximum severity was noticed from tasselling and six to eight weeks after silking which resulted in heavy loss. Infection that occurs at an earlier stage of development will result in greater yield loss. Late planted fields have a greater potential for yield loss. High plant populations create a thicker canopy and a favourable environment for disease development. High fertility fields favour fungal growth. Rain and high humidity levels favour disease development. Extended wet periods increase disease potential. All factors lead the build up of the pathogen inoculums. Yield loss in maize caused by diseases can be minimized by proper management strategies. For successful control of Northern leaf blight of maize, an integrated disease management approach, including awareness of conditions conducive to disease development, early detection of the disease, use of resistant varieties, good cultural practices, use of biopesticides and chemicals, is cost effective and sustainable way to minimize the yield losses.

Management:

Cultural practices:

Cultural practices that ensure the proper decomposition of stubble residue will reduce the amount of fungal inoculums present to infect the next maize crop. Proper tillage can reduce the disease severity by promoting the degradation of infected residue. Crop rotation with a non host can also help to reduce the disease severity of Northern leaf blight by providing the time for infected residue to break down and to prevent disease development in the subsequent corn crop by reducing the overwintering fungus. Cultural practices such as optimum plant density, planting date, crop rotation, healthy seed, balanced fertilization, weed and water management as per the recommendations are very essential tools for the management of NCLB.

Host plant resistance:

Varietal resistance is primary element of integrated disease management and is most acceptable method for farmers particularly under high land ecologies. Planting maize cultivars with good NCLB disease resistance is an economical way to manage the disease. Maize resistance can help to reduce the disease severity by limiting the number or size of NCLB lesions increasing the incubation period and/or by reducing the fungal spores. Deployment of resistant cultivars is most effective and cost-efficient way to control the Northern leaf blight. The lack/loss of substantial durable resistance in the maize genotypes may be attributed to the presence of variability and continuous change in racial spectrum of the pathogen (Pandurangegowda *et al*., 1993). The host plant resistance depends on the effectiveness of resistance against all the virulent races of the pathogen present in the region. Identification of variability among the isolates of a pathogen is an important step to devise a disease management programme for a particular region and for the development of disease resistant cultivars in many host pathogen system where major genes control resistance.

Preventive measures:

Preventive measures are important for fields at high risk of Northern corn leaf blight development. Fungicides can be used to slow disease spread and reduce overall severity. Foliar application of fungicides as spray is used to prevent infection of leaves during the growing season. If a field becomes infected and environmental conditions remain favourable for NCLB development, a fungicide application is profitable.

Application of fungicide at proper time is most essential for the management of NCLB. Fungicide application too early or late will not produce the desired results. NLB has rapid life cycle which may be as short as 1 week under favourable conditions. If a field becomes infested and environmental conditions remain favourable for NCLB development, a fungicide application may be profitable. Fungicide applications between VT and R3 have been shown to have the greatest efficacy against this disease.

Various foliar fungicides are available to control or suppress NLB development. Fungicides containing strobilurin trigger physiological responses in addition to disease control, such as improved nitrogen efficiency, more chlorophyll retention, antioxidant activity and delayed senescence. These physiological responses are associated with stress tolerance and improved stalk quality. Veerabhadraswamy *et al.,* (2014) found Strobilurin group fungicides in combination with triazole fungicides most effective in management of NCLB diseases. Mancozeb spray @ 0.25 per cent concentration and carbendazim + mancozeb (0.25%) significantly controls the NCLB of maize when applied at proper time (Reddy *et al.*, 2013). Propiconazole @ 0.1 per cent concentration is also very effective in controlling Turcicum leaf blight under field conditions.

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CHAPTER 12

MAIZE LANDRACES OF KASHMIR: AN OVERVIEW

Landraces are the primitive cultivars which are believed to be originated from the process of domestication without any systematic and sustainable breeding efforts. Landraces are highly variable crop populations that have been selected and cultivated by farmers to adapt to local environments and meet various needs. An important characteristic of landraces is that they display considerable genetic variation as compared to improved varieties. Besides good grain and straw quality genes, nature has bestowed these populations the ability or capacity to cope with new coming challenges and other socio-economic issues as they are reservoirs of useful genes having wider adaptability, wide resilience against many kinds of abiotic and biotic stresses such as cold, drought, insect pests and diseases. Plant breeders can use this variation to improve crop's resistance to stresses like cold, drought, heat and continuously evolving pests and diseases to increase yield directly thus meet the needs of increasing population. However, despite being the richest repositories of genetic diversity, source of valuable genes and unique resources for food security, they are becoming more threatened and suffering from genetic erosion. Therefore, there is need to conserve landraces because decrease in crop genetic diversity poses a risk to food security in the future, especially in light of a growing human population.

The systematic, coordinated and integrated *in situ* (where the plant is continually grown, managed and harvested in its original agricultural environment) and *ex situ* conservation (where seeds, plants, plant parts, tissues or cells are preserved in an artificial environment. The most common form of ex-situ conservation is through storage of material in gene-banks. The seeds are typically stored in laminated packets which are placed in containers and kept frozen at -18°C) of Landrace diversity is thus described as crucial in preventing the extinction of many of these local ecotypes. The conservationist has to work closely together with farmers in order to manage and monitor their landrace populations aiming at the long term preservation by maintaining genetic richness and evenness of the landrace diversity.

Maize or corn (*Zea mays*) is derived from the ancient word *mahiz* from the Taino language is a plant belonging to the family of grasses (*Poaceae*). The miracle of maize's birth is widely debated in science. Scientists believe people living in Central Mexico Balsas River

Valley developed corn at least 8,700 years ago (from where maize spread to other non-traditional areas and even to temperate belts of world and got established as a new crop). However, it is agreed that teosinte (a type of grass) is one of its genetic ancestors. What is unique is that maize's evolution advanced at the hands of farmers. Ancient Mesoamerican farmers realized this genetic mutation of teosinte resembled food and saved seeds from their best cobs to plant the next crop. Through generations of selective breeding based on the varying preferences of farmers and influenced by different climates and geography, maize evolved into a plant species full of diversity

Maize is cultivated globally being one of the most important cereal crops worldwide. The United States, China, Brazil and Mexico account for 70% of global production. India has 5% of corn acreage and contributes 2% of world production. Maize is not only an important human nutrient, but also a basic element of animal feed and raw material for manufacture of many industrial products. The products include corn starch, maltodextrins, corn oil, corn syrup and products of fermentation and distillation industries. It is also being recently used as biofuel.

In the state of Jammu and Kashmir particularly in Kashmir division, maize is the second most important crop after rice. It is a staple food of some tribal areas of Poonch, Rajouri, Bandipora, Badawah etc. where nomadic people such as Gujar and Bakarwall mainly depends on maize. In Kashmir, maize is grown as a sole crop at an altitude range of 1850-2300m above mean sea level. Generally maize is grown as rainfed crop on marginal lands particularly in hilly terrains of the Kashmir valley at longitude and latitude of 73.0-76.2E and 32.50-36.0N respectively. However, it is also found to occupy plain belts of the valley in few pockets where irrigation facility is either absent or inconvenient. In fact the plain belts of the valley (1450-1650m amsl), maize is usually grown as backyard /kitchen garden crop where maize plants are not allowed to go to seed development. The crop is usually consumed just before dough stage as roasted or boiled cob.

The maize landraces are usually genetically heterogeneous populations (each such population comprising a mixture of genotypes), and are typically selected by farmers for better adaptation to specific environment, prolificacy, flowering behaviour, yield, nutritive value and resistance to biotic and abiotic stresses. A maize landrace is mostly defined by the farmer in terms of ear characteristics; the ear type is usually maintained by the farmers through conservative selection in spite of considerable gene flow. In addition to farmer's management of maize landraces (e.g. sample size, selection decisions), the biology of the species (e.g. cross-pollination in case of maize) also plays a major role in structuring the maize populations

There has been significant decrease in maize genetic diversity in the last few decades due to replacement of maize landraces at a faster rate by cultivation of modern hybrids and by adopting modern agricultural systems. The use of a limited number of elite lines and synthetics heightens the risk of genetic uniformity in commercial maize production fields. Thus, maize breeders became more aware of the need for both maintaining genetic diversity among hybrid varieties and improving the management of genetic resources through the conservation of landraces. However, little impact was realized in Kashmir valley in the form of area enhancement under these modern varieties. The most important reason behind the fact was that hybrids are developed for more favourable environments which add non significant gain in the marginal environment. The expensive seed cost further aggravate the situation. In some cases diminishing returns were realized because of their poor adaptability under cold temperate conditions of Kashmir. Some landrace populations of maize are still popular among the farmers of Kashmir because of their some desirable traits. Farmers are growing landraces from early times either as a sole crop or in some cases intercropped with pulse crops such as beans, green gram etc. to increase the cropping intensity. The farmers go for intercropping because through traditional knowledge system they know the positive impact on compatibility of two crops and soil health aspect. A number of landrace populations of maize have been documented from Kashmir valley but presently few are in the farmer's domain.

Reason of their Popularity:

The main reason of their popularity even in the circumstances of availability of high yielding varieties bred by public and private sector are:

- **Good adaptation:** Their adaptation to specific agro-ecologies and have usually assumed a niche status. They have very good population buffering.
- **Wide resistance to natural factors:** These land race populations have wide range of genetic variability and adaptability. They possess the genes for tolerance to various biotic and abiotic stresses. Most important to mention are drought, cold, insect, pest resistance etc.

- They are early maturing and thus vacate the field early and escape the cold injury risk at later stages of crop growth. Snowfall is likely to be expected in the month of September particularly in the hilly terrains when the crop is under dough stage.
- Their very good culm quality usually thin and succulent stems are highly relished by the cattle in the lean season when there is no other fodder crop available.
- As maize is grown usually on marginal lands and under low input environment and the areas where irrigation facility is absent. Since these landraces have much specific adaptability, they thrive best even under low input conditions. Known, locally-adapted, open-pollinated maize with its more variable flowering times is often a "safer" crop under marginal farming conditions.
- **Good grain quality:** Because of very good grain quality they are mostly preferred over hybrids and synthetics bred by Mountain Crop Research Station (SKUAST-K) meant for the purpose for different agro-ecologies of Kashmir and from outside sources of equivalent ecologies.
- **Food and fodder value:** These land races usually serve as a staple food of 15% of the population of Kashmir valley. The maize kernels are ground to fine flour (locally called *Makai* a*tta*). The unleavened bread is finally prepared of this flour which is much liked by the local people even the rice consumers of Kashmir. The bread is usually supplemented with locally prepared ghee which adds taste and aroma to the unleavened bread. The byproduct of the grinding process is rough maize flour (locally called *Satoo*) and is consumed with salt tea. It is used throughout Kashmir valley as a breakfast food and is cheaper alternative to bread made up of wheat for low income families. In some cases maize is consumed just like rice. After boiling maize grains a sticky dish is prepared and is supplemented with curd. This is highly relished by elderly people in the hilly areas and locally called makai wart. In the local system of medicine it is recommended to diabetic patients and those having urinary problems. *Satoo* (rough flour) used as breakfast food, *Atta* (fine flour) for bread making and *Makai wart* (boiled kernals of maize just like rice).
- The roasted and boiled cobs of local land races fetch a very good market rate because of very high taste and good sugary content. When fodder values of these landraces are concerned, their thin and succulent stems (culm) are highly relished by cattle and do not leave any part of it unconsumed. Since during winter the valley remains cut off for

months together from outer part of the world and these hilly terrains have no alternative except to use maize stover as cattle fodder.

- **Conservation of biodiversity:** Since farmers are continuously growing these landraces over years, they are conserving and utilizing the maize biodiversity.
- Resistance against climate change: Landraces of maize are best weapons to combat the challenge of climate change. These cultures conserve the tremendous genetic variability which can serve as wealth for overcoming future challenges like new biotic and abiotic stresses in the scenario of climate change. There shall remain no weapon, besides these allelic resources for the crop development.
- These landraces with so many potentials are losing their popularity and are gradually going out of farmers' domain and becoming extinct. These are facing a tough competition from newly developed hybrids and synthetic varieties. The main reasons of losing the farmer's expectations and few challenges before these erstwhile popular landraces are:
- **Low yielding potential:** Since maize landraces populations are generally low yielders when compared top modern varieties. As a result they are being replaced by high yielding hybrids and synthetic varieties although at a slow rate.
- **Low resilience to some biotic stresses:** These farmers varieties are showing low or no resistance to worldly famous maize diseases such as *Turcicum* leaf blight and common rust which are taking a heavy toll of the crop. In disease favourable years there is significant damage in terms of low yield production and reduction in straw quality.
- **Lower sensitivity to inputs:** These land races are highly stable and adapted under specific agro-ecologies. These respond at a very slow rate to favourable environments and to costlier inputs such as inorganic and bio-fertilizers.
- **Socio economic plight of the farmers:** People engaged with maize production are resource poor farmers and are socially and economically backward. They are not growing their landraces on modern scientific lines. It is the need of hour to conserve these maize landrace populations. There is much probability of these maize cultures to become extinct by the very near future. Big challenge before plant breeders is therefore to collect conserve, genetically enhance and to utilize these populations so as to get themselves prepared for forthcoming challenges.

Utility of Maize Landraces in Crop Improvement:

The utilization of genetic diversity of landraces in breeding programs started with development of the first inbred lines in Yugoslavia form Ruma Golden Dent, Vukovar Dent, Šidski, Beljski and Novi Sad Golden Dent populations. Crosses of self pollinated landraces with American inbred lines, which expressed a high level of heterosis, were the base for development of line-hybrids. First Yugoslav maize hybrids were created from inbred lines of local origin and foreign inbred lines genetically divergent from local germplasm. In modern maize breeding program landraces are used for creation of broad base synthetic populations, development of core collections and as potential sources of favorable traits.

- **Agronomic performance:**

Two objectives in evaluating maize landraces are (a) to identify the best local populations that could be used broadly and, (b) to identify populations that will be starting material for crop improvement. Broad based pools formed using promising landraces for specific traits are excellent material for population improvement programmes. Population improvement through recurrent selection aims at increasing the frequency of favourable genes in population progressively over successive generations, while maintaining reasonable levels of genetic variability. For example, at Vivekananda Parvatiya Krishi Anusandhan Sansthan (VPKAS), Almora Utranchal, landraces from Kashmir as well as from Utranachal were effectively utilized for developing a broad based gene pool. Using this germplasm, several inbred lines and hybrids that are well adapted to hill areas were derived. The popular hybrids include Him-129, (yellow, flint, 85-90 days maturity, highly tolerant to Turcicum leaf blight); Him-128 and several 'Vivek' hybrids.

- **Quality traits:**

Characterization of genetic diversity of maize landraces aids efficient exploring of the allelic variation for genetic improvement of economically desirable traits, such as grain quality. Maize is a relevant food source, so the quantification of the nutritionally important grain constituents is important for the best exploitation of different genotypes. In this context, the landraces represent a good source of genetic variability and may help to identify the most suitable materials for the development of more nutritious foods. Many studies have documented genetic and phenotypic variability for grain composition traits in maize. Promising maize landraces with highest concentration of lutein, zeaxanthin and cryotoxanthin (precursor of Vitamin A) have been identified at the Institute for Agrobotany, Hungry and they are being utilized as a source material to transfer these valuable traits in improved elite hybrids and inbreds.

- **Drought tolerance:**

Drought can be defined as the absence of adequate moisture necessary for normal plant growth and to complete the life cycle. It is a "single most common cause of severe food shortage" (FAO) in developing countries and predicted global warming will increase drought impact on crop production. Drought tolerance is the most difficult task for maize breeders to be solved. It is polygenic and complex trait with high genotype x environment interaction. Moreover, this stress occurs randomly in timing and severity, making identification of drought tolerant genotypes more difficult. Genetic Diversity of Maize Landraces as sources of drought tolerance were evolved and examined by CIMMYT for use in maize breeding programs and traits like flowering date (anthesis-silking interval, ASI), ears per plant (bareness), leaf rolling, tassel size and stay green considering tremendous genetic diversity and importance of drought for maize production.

- **Source of Male Sterility:**

Absence of pollen and plant inability to produce functional pollen grains is known as male sterility. Male sterility can be determined by nuclear (genetic male sterility) or cytoplasmic (cytoplasmic genetic male sterility – CGMS) genes. CGMS (onwards referred to as CMS) is successfully used in commercial production of hybrid seed, avoiding the drawbacks of hand or mechanical emasculation. Identification of CMS types is important because commercial production of maize hybrid seed today stands upon utilization of C and S cytoplasmic types, as self-pollination in plants can severely jeopardize its production. Detasseling (removal of flowers from maize plants by hand) can be replaced by introducing male sterility in maize. This reduces possibility of self-pollination and also saves seed producers millions of dollars per year in labor costs. Three main types of CMS were identified in maize: CMS-T, CMS-S and CMS-C. Male sterile cytoplasm is distinguished by specific nuclear genes (Rf genes) that restore pollen fertility. These genes, restorers of fertility, suppress the male-sterile effect of the cytoplasm, allowing the production of viable pollen. The use of uniform materials can be a threat in crop production and genetic vulnerability must be a constant concern in plant breeding for all species. An example is the extensive use of CMS-T in 1950s and 1960s, which showed to be extremely susceptible to *Helminthosporium maydis* race T. Severe yield losses occurred in the United States in 1970s and the next year in other regions of the world, due to the *Helminthosporium maydis* pandemic. For new CMS sources landrace genotypes worldwide were searched and one source was found within Maize Research Institute gene bank collection. Tester lines containing nuclear Rf genes are traditionally used for identification and classification of CMS types.

Collection and evaluation of maize land races are basic to maize improvement programs for sustainable agriculture. Adequate characterization for agronomic and morphological traits is necessary to facilitate utilization of landraces by breeders. To achieve this, landraces of maize need to be characterized for morphological, agronomic and other stress related traits of interest. There exists a wide genetic variability in maize, making process of selection promising for traits of economic importance.

Improvement of maize landrace populations:

- Since landraces are having wide genetic variability. Their genetic enhancement for yield and other morpho-agronomic traits can simply be obtained by mass selection. Few selection cycles can give a significant genetic gain over the base population. Thus various economic traits can be improved through this method.
- Population improvement programme: Few simple recurrent selection cycles can genetically improve the base population of these landraces because they possess broad spectrum genetic variability within the population for various economic traits. This not only improves the population *per se* but improved inbreds can be derived from the populations for hybrid development.
- Biotechnological interventions: Few economic traits available in maize landraces can be rectified by using the latest tool of biotechnology such as molecular selections and other tools. The current revolution in DNA technologies offers tremendous opportunities to understand the genetic relationships and diversity among maize landraces and improved cultivars. Molecular-marker-based diversity assessment has provided valuable information on the extent and distribution of genetic diversity in global maize germplasm. Next-generation sequencing and high density genotyping technologies, including GBS, will provide greater insights into the structure and organization of maize genome, and speed up the discovery and use of new and useful alleles available in maize landraces for maize improvement. Additionally, intensive and concerted efforts (e.g. LAMP and US-GEM) are needed for a better

understanding of the breeding value of the maize genetic resources available worldwide including landraces.

- Innovative approaches for crop improvement: - New scientific management technologies can be popularized in the farming community like proper crop husbandry practices for better production which in turn can improve socioeconomic plight of the farmers.
- Participating plant breeding (PPB) approaches: PPB will work with farmers aspirations and needs and develop the varieties as per the priorities of clients. This is because in formal breeding programme varieties are generally developed at favourable environments but are proposed for different environments. The released variety is in real practice not in multiplication chain and is thus not available. The expensive cost and long lag phase from development of variety and actual availability to farmers also play a role in slow adoption of good varieties. The resource poor farmers particularly in maize are generally located at marginal environments and such conditions are not being given due consideration. It is here these landraces can be popularized after genetic enhance and genetic purification right in the farmers fields. The community seed production units can be established for informal seed multiplication chain. Thus participatory role is needed where farmers can be directly involved and agro-ecology specific varieties can be designed. This will economize time and resources viz-a-viz maintain the maize genetic diversity in-situ.

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Temperate Maize Cultivation

Bhumi Publishing

ISBN 978-93-88901-00-0