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Maize-adaptability, stress management and uses: An overview

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Abstract
Maize, belonging to family poaceae, is cultivated in 166 countries of the world. Maize crop is of tropical origin and keeps the highest genetic yield potential in the cereal group. This crop is originated primarily from Central America and Mexico. In India, maize crop is cultivated in diverse climatic conditions owing to its wider adaptability. In India, a number of maize based cropping systems like have been identified in different agro-climatic zones. Within Trans Gangetic Plain agro-climatic zone, cropping systems such as maize *fb* wheat, maize *fb* paddy *fb* wheat etc. are economically viable and successfully adopted by the farmers. Climate change is going to effect every inch and corner of agriculture worldwide. Frequent floods and water logging problem is going to affect approximately 18 percent of total area under maize cultivation in South as well as South-east Asia, which in turn, may cause losses of 25-30% annually. In this scenario of climate change, smart technologies play pivotal role in bringing resilience in the agriculture production systems. Technologies zero tillage or raised bed planting technologies prove worthwhile in coping up the harmful impact of climate change along with conservation of natural resources like water. Biotic stress can be tackled well through integrated approach whether to manage weeds or insect-pests. Integrated use of tembotrione at 36.7 g/ha dose sole/mixing with atrazine at 208 g/ha dose as intra-row and hand weeding (inter-row) realized equal level of control of weeds and maize yield with foliar spray of tembotrione at 110 g/ha sole/mixing with atrazine at 625 g/ha dose. Prevention of crop from various abiotic stresses like extreme dry conditions, osmotic stress, extreme temperature stress etc. can provide avenue to make the maize production climate resilient. Maize crop can be stored as silage for use as fodder during lean period. Harvesting of crop at proper stage, chopping and packing in silo at proper moisture content followed by fermentation process under anaerobic conditions makes a good quality silage which is highly palatable and preferred by the farm animals. Maize crop not only act as source of food and dry/green fodder but also meets other purposes like novel foods such as quality protein maize, waxy corn, and amylo-maize.

Keywords: Maize, climate change, abiotic stress, silage, novel foods

Introduction

Maize (*Zea mays* L), being adapted to diverse agro-climatic conditions, is one of the most versatile crops. Maize crop is cultivated in 166 countries over the globe for one or another purpose. Maize, a grass of C_4 mechanism, is originated in tropics, tops in the cereals in terms of genetic yield potential. Globally, maize is grown on area of 197 mha having production of 1148 mtonnes and average productivity of 58.24 q/ha [1]. In 2020-21, India produced 30 mtonnes of maize from an area of 9.9 mha (agricoop.nic.in). Although maize acts as a staple food and good quality feed, it also provides raw material to a number of industrial products such as starch, maize oil, maize protein, beverages, sweeteners, medicine industry, paper industries etc. The multiple uses of maize crop make it worthwhile in meeting the recurrent demands. These unique features of maize crop make it an appropriate and promising candidate for improving agriculture income and farmers' livelihoods in the country. Maize crop can be grown almost all the weather conditions such as *Kharif*, Winter, Spring and Summer season. In the scenario of climate change due increase in average temperature (2.0 °C) of the globe, productivity of maize crop is going to be reduced according to the simulation outcomes of CERES-Maize [2]. Change in thermal regimes of the globe will also affect incidence of biotic and abiotic pressures on the crop which in turn, will require region specific technological interventions to develop the climate resilient production systems. Development of eco-friendly climate smart technologies like mulching, bed planting, short duration varieties, integrated crop management etc. play critical role to maintain agriculture sustainability without compromising the income of ultimate stakeholders i.e., farmers.

Origin and Distribution

Maize, containing chromosome number 2n=20, is a prime member of family Poaceae [3]. Out of four species in the genus *Zea*, *Zea mays* L. is economically viable and grown globally on large scale. It is considered to be originated primarily from Central America and Mexico. Globally, USA tops in the context of area under maize crop. India ranks fourth after Brazil, Republic of China, and Mexico. Furthermore, USA also stands first in terms of total production followed by China. In Indian scenario, states like Uttar Pradesh (UP), Bihar, MP and Punjab mainly contribute in the food bowl. UP out yields other states with respect to area and total production but Andhra Pradesh records in terms of productivity [4, 5].

Botany of maize plant

Being monoecious, maize plant has separate male and female flowers which are known as tessel and silk, respectively. Maize plant has protandrous characteristic means male flower emerges in advance to female part. Maize is determinate in growth habit. Maize plant exercises C_4 pathway of photosynthesis as oxaloacetate (4-C compound) is the first product synthesized in photosynthetic process. The role of Ribulose-1,5-biphosphate is completely omitted in this pathway through various biochemical and internal modifications of leaves [6]. Figure 1 depicts the different parts of a maize plant.

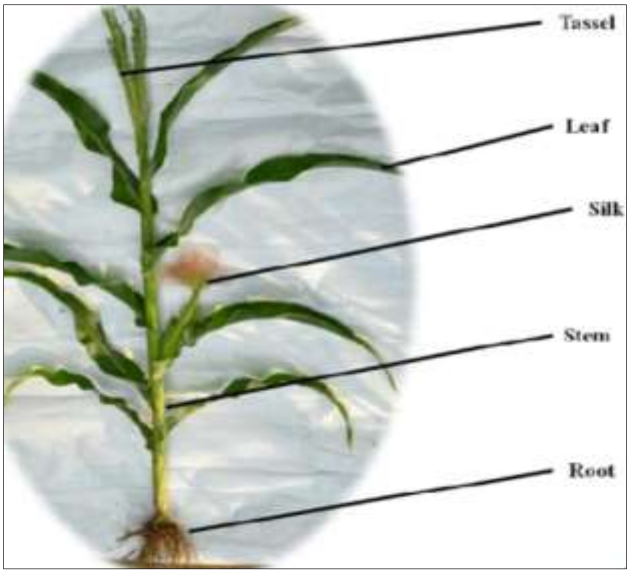

Fig 1: Parts of a maize plant

Every male spikelet in the flower contains 2 functional florets and each floret has 2 fine scales known as lemma and palea, 3 anthers, 2 lodicules and 1 pistil. On an average, each tassel produces around 7 thousand anthers with about 3.5 thousand pollens/anther, hence, each tassel may produce approximately 2.5 Crore pollens. The pollens are very minute and can be easily transported by wind due to light weight. Cross-pollination in maize crop is accomplished primarily through protandrous development and anemophily. In female part, first basal protuberances appear then development advances towards the tip. The joined carpels develop into the pericarp of the kernel, grow further until they fully cover the ovule. Two anterior carpels facing top of the female part grow as long hairs and develop into the style, called silk. These threads like structures are covered with a number of hairs known as trichomes. The female inflorescence, mainly exist as an auxillary bud in the middle of the main stem, develops from one or more lateral branches (shanks). The femle inflorescence remains covered with layers of husk leaves. Table 1 describes various developmental stages of maize crop from sowing to harvesting [7]

Table 1: Growth stages of maize plant

Code	Stage Name	Brief Description
VE	Emergence	Germination of seed followed by growth of coleoptile.
V1	First Leaf Collar	Elongation of nodal roots, collar of lowest leaf, with round tip, becomes visible.
V3	Third Leaf Collar	Collar of 3^{rd} leaf with pointed end becomes visible.
V7	Seven Leaf Collar	Collar of 7^{th} leaf with pointed end becomes visible.
VT	Tesseling	Cessation of vegetative growth, Emergence of the tessel at the top of the plant.
R1	Silking	First reproductive stage when silks become visible out of the husks.
R3	Milk Stage	Developing grains are filled with milky material.
R4	Dough Stage	Developing grains have dough like consistency inside.
R5	Dent Stage	Dent develops on the kernels and milk line advances towards the tip.
R6	Physiological Maturity	Kernels reach at maximum dry matter accumulation followed by formation of a black layer at the base of the kernel.

Maize and Crop Diversification

Due to the practices of monoculture as a result of Green Revolution in India, diversification of cropping systems has become need of the hour. Diversification not only provides avenues for alternate crops but also prove promising in having an array of sources of income for farmers while maintaining soil health. Wider adaptability of maize crop under varied climatic conditions fits it in a number of crop rotations in the country. Following are the major maize based cropping systems in agroclimatic regions of the country [8]:

Table 2: Maize based cropping systems in agroclimatic regions

Name of the region	Cropping system	
	Irrigated	Rainfed
Western Himalayan Region	Maize-Wheat/Barley Maize-Pea-Wheat Maize-Mustard/Potato	Maize-Raya Sarson/Gobhi Sarson Maize-Pulses
Eastern Himalayan Region	Summer Paddy-Maize-Oilseed Maize-Maize Maize-Maize-Pulses	*Sesamum*-Paddy/Maize
Lower Gangetic Plain Region	Autumn Paddy-Maize *Corchorus*-Paddy-Maize	Paddy-Maize
Middle Gangetic Plain Region	Maize-Potato-Wheat Maize-Wheat Maize-Wheat-Mungbean Maize-Wheat-Blackgram Maize-Sugarcane-Mungbean	Maize-Wheat
Upper Gangetic Plain Region	Maize-Whea Maize-Potato-Wheat Maize-Potato-Sunflower Rice-Potato-Maize	Maize-Wheat Maize-*Hordeum*
Trans Gangetic Plain Region	Maize-Wheat Maize-Potato-Wheat Maize-Potato-Onion	-
Eastern Plateau & Hills Region	Maize-Groundnut-Summer Vegetables Maize-Wheat-Summer Vegetables	Rice-Early Potato-Maize *Corchorus*-Maize-Legume
Central Plateau & Hills Region	Maize-Wheat	Maize-Groundnut
Western Plateau & Hills Region	Sugarcane + Maize	-
Southern Plateau & Hills Region	Maize-Paddy Paddy-Maize	*Jawar*-Maize Maize-*Jawar*-Legume
East Coast Plain And Hills Region	Rice-Maize-*Bajra* Maize-Paddy Paddy-Paddy-Maize	Maize-Maize-*Bajra* Rice-Maize + Legume
West Coast Plain And Hills Region	Maize-Pulse Crops Paddy-Maize	Paddy-Maize Groundnut-Maize
Gujarat Plains And Hills Region	Maize-Wheat	Paddy-Maize
Western Dry Region	Maize-*Raya Sarson*; Maize- Gram	Maize+Pulse Crops
Island Region	Paddy-Maize	Maize-Paddy Paddy-Maize + Legume Paddy-Paddy-Maize

Maize crop and climate

Crop production and allied sectors are highly susceptible to the harmful effects of climate change [9]. In this scenario of diverse and marginal conditions, agriculture must be able to adequately produce while maintaining better productivity and sustainability. Agriculture and related enterprises are facing inevitable pressure to meet food supply needs of ever growing human population globally [10, 11] because this demand is estimated to be doubled by 2050 [12]. The rise in global temperature is an apparent process being recorded since recent decades which further accelerates the phenomenon of climate change. Prevalence of rising temperature and climate change conditions have initiated recurrent unfavorable weather events like droughts, non-distributed rainfall etc., that certainly affect production and productivity of agriculture. Major and notable direct effects of the climate change on crops and other enterprises will be mediated by fluctuations in low and high temperature, non-uniform rainfall, change length of grain filling period, and occurrence of extreme events in relation to development of crop [13, 14, 15, 16]. Approximately 18 percent under maize cultivation the region of South and South-east Asia is affected by recurrent floods and water stagnation which in turn, lead to loss of total production by 25-30 percent [17].

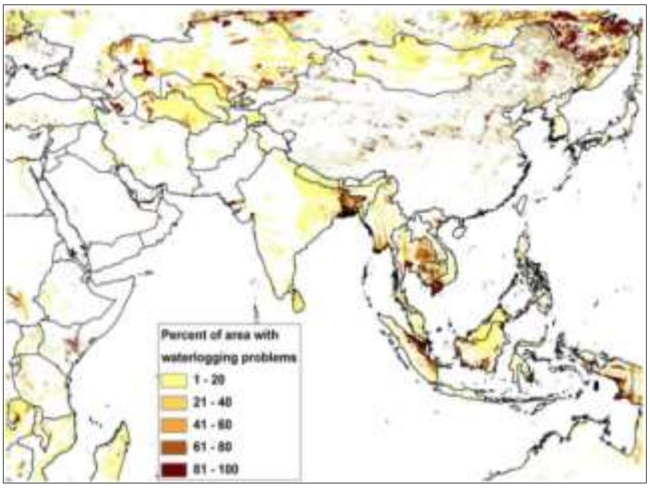

Fig 2: Water logging risk in Asia. [41, 42, 43, 44]

It has been predicted that, by the year 2025, the maize crop is going to be major crop with remarkable production at world level. In the developing countries, the demand for the maize crop is going to get doubled by the year 2050 [18]. Maize, keeping highest productivity capacity in cereal group, promising source of food, green fodder, and other needs for about 6,000 million people, and at the same time, an unexpected rise in demand for cereals is expected all over the world [19]. In United States of America, a hike in productivity of maize crop from 15 q/ha to 85 q/ha has been recorded during the period in the early 1900s to the starting of 2000s [20, 21]. In this appreciable and major result, maize productivity is closely related to number of plants per unit area [22, 23] Critically showed the direct effects of plant density on the stability of maize productivity which mainly occurs because of missing plants, high plant-to-plant variability, stalk lodging, and enhanced barrenness (high density) [24]. Studies on two separate hybrid sets and revealed a highly positive linear relationship between per plant grain yield at 0.74 plants per m^2 with plant yield potential (PYP) values of hybrids (Fig.4).

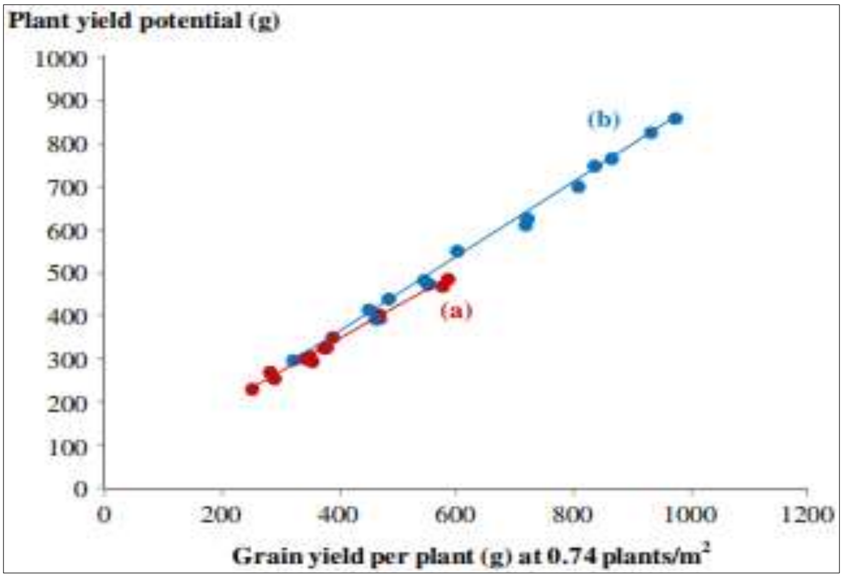

Fig 4: Relationship between maize grain yield/plant and plant yield potential of two hybrids

Any technology that increases the resource use efficiency, decreases the load on resource base, maintains yield potential of the maize crop while alleviating the harmful effect of climatic vagaries like heat stress, drought etc. can be termed as climate smart technology (CST). Adoption of zero tillage in rice follow hybrid maize has become a source of inspiration for technological inventions in India. For example, in the state of Andhra Pradesh, cultivation of maize crop with zero tillage technology (Fig.5) is approximately on an area of 2 lakh ha and further spreading in other adjoining states such as Tamil Nadu, Karnataka etc. The productivity of maize crop in zero till single cross hybrid cultivation belt is as high as 9 tonnes/ha [25]. In zero tillage, to control weeds, blanket spray of gramoxone 24 SL (a non-selective herbicide) at 1.25 l/ha dose 24 hours before sowing with zero tillage makes the sowing operations run smooth. Ridge sowing or flatbed planting is considered best for cultivation underwater scarcity conditions. In this method, Irrigation water can be saved upto 20-30% [26].

Fig 5: Maize crop planted with zero tillage technology and on raised beds

Biotic Stress Management

Wider row spacing along with congenial environment allows proliferative growth of weeds which compete with maize crop for space, nutrients and water [27]. Concluded that longer duration of competition between weeds and maize crop reduced the grain yield by 31-40 percent. Efficient weed management approaches play critical role in maize production and productivity. It is of utmost importance to follow suitable weed management practices within 6–8 weeks after sowing. The maize crop kept free from weeds in first 30–45 days after sowing (critical period of crop-weed competition) realizes almost equal yield levels to the plot that is maintained weed free for entire life span. Knowledge regarding the type and nature of weed species is the prerequisite for effective and economic weed management. Table 3 shows different types of weeds that infest maize crop during the crop cycle:

Table 3: Categorization of weeds that infest maize fields

Type of weeds	Name
Grassy weeds	*Echinochloa colonum, Echinochloa crusgalli, Acrachne racemosa, Digitaria sanguinalis, Dactyloctenium aegyptium. Paspalum dilatatum* and *Cynodon dactylon*
Broad leaf weeds	*Trianthema portulacastrum, Trianthema monogyna, Digera sp., Commelina sp., Phyllanthus sp., Xanthium sp., Boerhavia diffusa, and Parthenium sp.*
Sedges	*Cyperus spp.*

In maize crop, weeds can be controlled by various approaches (Table 4) *viz.* cultural/mechanical, biological and use of herbicides. Following are the details of the approaches that can be followed for management of weeds in maize crop that can be applied alone or in combination with each other as per the suitability:

Table 4: Management of weeds in maize crop by different approaches

Approach	Details
Cultural/ Mechanical	Cultural practices include hand weeding or manually using wheel hand hoe at 15–30 DAS. Tractor drawn cultivator can also be used which saves time. Mulching includes spreading of crop by products, thin plastic sheets, crop stalks, dried grass or other dead material on the surface of soil in the standing crop. This practice regulates the soil temperature with minimum fluctuation, conservation of soil moisture and less germination of weeds in field crops [28, 29].
Weedicide use	Application of atrataf 50 WP (Atrazine) at 2000 g per ha dose on medium-fine textured soils and 1250 g per ha in coarse textured soils within 24-48 hours after sowing, using 500 l of water prevents the emergence of weeds by preventing germination. As the crop field remains vacant till crop emergence, so pre-emergence herbicide spray is a promising approach to minimize the intensity of competition posed by weeds on maize crop. Spray of laudis 420 SC (tembotrione) at 0.262 l per ha in 375 l of water at about 20 days after planting effectively controls almost all types of weed species in the maize field. Spray of 2,4-D amine salt 58 SL on standing crop (20-25 DAS) at 0.5 l/ha dose to control sedges such as *Cyperus rotundus* in 375 L of water. This herbicide also controls broad leaf weeds that infest the maize crop.

[4, 27, 28]

[30] studied the effectiveness of weed management approaches, whose results were assessed by deriving various indices such as weed index, weed control efficiency and weed control index (Table 5).

Table 5: Effectiveness of various weed management approaches followed in maize crop

Treatment	Dry matter accumulation (75 DAS)	Weed Index	Weed Control Efficiency (%)	Weed Control Index
Atrazine at 750 g a.i./ha + Pendimethalin at 750 g a.i./ha (within 24 hrs of planting)	40.40	32.59	58.76	62.21
Atrazine at 1000 g a.i./ha (pre-em)+residue* at 25 q/ha	59.60	41.73	36.84	44.26
Pendimethalin at 1000 g a.i./ha (preem)+residue at 25 q/ha	72.80	36.96	28.08	31.91
Atrazine at 750 g a.i./ha (preem) *fb* Halosulfuron at 90 g/ha (30 DAS)	31.72	33.66	35.08	70.33
Atrazine at 1000 g a.i./ha (preem) *fb* Tembotrione at 120 g a.i./ ha (30 DAS)	84.00	28.99	16.66	21.44
Pendimethalin at 750 g a.i./ha (pre-em)+Halosulfuron at 90 g/ ha (30 DAS)	84.80	32.39	27.18	20.69
Pendimethalin at 750 g a.i./ha (preem)+Tembotrione at 120 g a.i./ha (30 DAS)	94.68	40.95	27.18	11.45
Halosulfuron at 90 g/ha+Tembotrione at 120 g a.i./ha (Tank mix,30 DAS)	56.00	31.42	46.50	47.62
Halosulfuron at 90 g/ha *fb* Tembotrione at 120 g a.i./ha (30 DAS)	31.48	28.02	42.11	70.56
Weedy check	106.92	67.22	00	0.00
Weed-free (Control)	4.00	00	97.37	96.26

*mulching with wheat straw within 6-7 DAS.

[31] Revealed that integration of weedicide spray with manual removal of weeds registered effective manage of weeds without harming grain yield of maize. It has been concluded that spray of tembotrione at 36.7 g per ha dose alone/tank mixing with atrazine at 0.208 kg/ per ha as band application and manual removal of weeds from inter-row area in maize field realized weed control and maize grain yield b almost equal to that of foliar spray of tembotrione at 110 g/ha alone/tank mixture with atrazine at 0.625 kg per ha.

Integrated Pest Management (IPM)

IPM consists of rational and need based use of all possible approaches to keep the insect-pest population below economic threshold level (ETL) without endangering the density of natural enemies and overall agroecology. The different components of IPM include cultural, biological and chemical control of insect-pests. Table 6 depicts the brief details of various components of the IPM:

Table 6: Different approaches for the pest management in maize crop

Approach	Details
Cultural	Deep summer ploughing. Cultivation of legume crops as an inter crop reduces incidence of stem borer in maize. Use of good quality and decomposed FYM to reduce termite attack. Judicious use of fertilizers.
Mechanical	Cutting and destroying infected plants. Use of traps such as pheromone or light traps to break the reproduction cycle.
Chemical	Maize stem borer can be managed by foliar spray of coragen 18.5 SC at 75 ml per ha using 150 l water/ha. To control fall armyworm, coragen 18.5 SC at 0.5 ml/l of water or Delegate 11.7 SC at 0.5 ml/litre of water or Missile 5 SG at 0.4 g/l of water can be sprayed. To prevent attack of shoot fly especially in spring maize, seed treatment with Gaucho 600 FS @ 6 ml/kg of seed gives positive results.
Biological	Biological control of insect-pests comprises of using living entities either by parasitizing or predating the target pests. Stem borer and other pests in maize crop can be controlled by spray of neemazal (1%) with a dose of 0.3 l per ha. Use of tricho-cards (with 40,000 egg of *Corcyra* parasitized by *Trichogramma chilonis* per card) in the maize fields helps keep the attack of maize stem borer below ETL. Use of the tricho-cards should be avoided during rainy days.

Abiotic stress management

Reduction in production and productivity of annual crops is in process as abiotic stress like drought, is at the top of the constraint list [32]. Extreme of water regimes, temperature regime, and osmotic stress are major abiotic factors that affect maize production at world level [33]. Maize development and final grain yield are severely affected by waterlogging, low/high temperature, and occurrence of drought [34]. Similarly, ambient temperature regimes are predicted to fluctuate which derives the climate change, which in turn, alter frequency and the intensity of drought events in majority of maize cultivating zones of the world [35]. As concluded in some researches, rise in temperature in major maize growing regions of the world, maturity times may shorten. At the same time, rise in temperatures will alter metabolic processes, reduction in carbon uptake, enhanced pollen desiccation, less pollination, seed setting and finally grain yield [36, 37]. In addition to the broad-scale variables altering rainfall distribution and intensity, increase in average temperature regimes enhances moisture stress mainly by decreasing soil moisture content, increasing rate of evapo-transpiration [38, 39].

Table 7: Major abiotic stresses and their management strategies

Abiotic stress	Management strategy
Drought stress	Drought escape- Escaping the event of drought is a mechanism by which plant complete their life span before the onset of drought. Drought avoidance- In drought avoidance, plants enhance uptake of soil moisture along with curbing the loss of water from plant surface. Drought tolerance- In this, Plants develop metabolic systems to conserve more and more water. Major mechanisms include osmotic adjustment and enhanced level of antioxidants.
Salt stress	Foliar application selenium (1 µM) decreases the inhibitory effects of salt stress. For instance, [40] used 15 days old maize plants to evaluate various concentrations of Na_2SeO_3 (at concentration of 0, 1, 5 and 25 µM). Concluded that the spray of Se @ 1 µM improved the rate of net photosynthesis, defense process by the antioxidants and decrease loss of chloroplast ultra structure due to sodium chloride.
Low temperature stress	[41] Studied the effect of pre-treatment of young seedlings of maize with 0.5 mM salicylic acid, and concluded that pre-treatment with salicylic acid downgraded the activity of catalase, increased the antioxidant activity of peroxidases and glutathione reductase, which in turn resulted in higher level of tolerance to freezing in maize plants.
High temperature stress	Selection of suitable hybrids of maize. Timely sowing of spring maize. In late sown conditions, tesseling stage interferes with increase in air temperature which causes desiccation of pollen grains and hinders seed setting. Development of favorable microclimatic by frequent irrigation application. Sprinkler system of irrigation helps to alleviate the high temperature stress. Keeping the organic waste as mulch material helps in maintaining favorable soil regime.

Maize as a preserved fodder for lean period

India is rich in livestock sector which is largest in the world. It comprises of 56.7 percent buffaloes, 12.5 percent cattle, 20.4 percent small ruminants, 1.5 percent pigs and 3.1 percent poultry [42]. Adoption of intensive production systems, especially based on cereals and cash crops, led to a reduction in area under fodders. It further leads to build up of strong pressure to meet the fodder supply targets. Fresh cut forages are an indispensible part of animal feed which act as rich and low cost bearing source of roughage and nutrient such as protein, vitamins and minerals. To achieve optimum level of milk production, a milch animal requires year round supply of approximately 40 to 50 kg of nutritious green or dry fodder. In the scenario of increase in the production and productivity of maize crop is India, the biomass availability from the maize crop is also increasing linearly. Out of various non-legumenous fodders i.e., sorghum and pearl millet, maize is promising in providing better quantity and nutritional quality of biomass. Crude protein and *in vitro* dry matter digestibility (IVDMD) are 2 major factors which determine the nutritional quality of any fodder. These parameters are on higher side in maize relative to its sorghum and pearl millet [43] (Table 8).

Table 8: Nutritional quality of non-legume fodder crops

Type of fodder	Developmental stage	Harvesting time (DAS)	Crude protein (%)	IVDMD
Maize	Silking to milk	55-65	11-8	68-52
Sorghum	Initiation of flowering	70-80	8-7	60-57
Bajra	Booting	45-55	10-7	62-55

In contrast to maize crop, sorghum (*Jawar*) and pearl millet contain anti-quality components which may prove harmful to animal health. For instance, sorghum is although cultivated on large area, contains the anti-nutritional component known as prussic acid. So maize tops among the non-leguminous fodders in terms of quality and quantity of biomass, so it provides good avenue for use a freshly cut fodder or as preserved fodder.

Maize and ensiling process: Currently, India faces a shortage of green fodder by 61.1 percent, dry biomass of crops by 21.9 percent and concentrates by 64 percent. In addition to this, At the same time, relative to the total area under crops, the cropped area under fodder crops is only 4.2-4.4 percent. Furthermore, there exists a very limited scope of horizontal spread of fodder crops owing to increasing pressure on agricultural land. Therefore, conservation of fodder is a key element to meet the year round requirement of fodder especially during lean period i.e., Nov-Dec and May-June. Amongst the other methods of preservation, ensilage has many advantages in terms of availability of nutrients. Silage is prepared by process of fermentation of nutrients under anaerobic conditions. The fermentation process is accomplished by the micro-organisms and the growth of *Clostridium* sp. is checked to minimize the loss of nutrients. Optimum moisture content and presence of soluble carbohydrates is pre-requisite for proper fermentation process to prepare good quality silage. The soluble carbohydrates are converted to lactic acid during fermentation.

Steps in silage making: The process of preparing the silage, starting from harvesting of crop to packing of silo pits, can be divided into 6 steps [44].

Assessing the amount of silage required: Imagine one has to prepare silage for one cow with a feeding period of 90 days. He wants to meet the requirement of 50 percent of the total animal supply i.e., 40 kg of feed. Moisture content of the silage needs to be at 75 percent. Losses due to spoilage can go up to 15 percent, on an average. Density of the silage is 0.8 metric tonnes/m^3. To meet these requirement, following will be the amount of silage and size of silo pit to prepare the silage:
Requirement of feed (kg)-1 (animal) x 20 (50 percent of total ration) x 90 (period of requirment) = 1800 kg
As spoilage losses can go up to 15 percent, therefore, 15 percent more silage will be required i.e., 0.15 x 1800 kg = 2070 kg silage to feed to 1 animal for 90 days.
Requirement of silo space: 2070 kg/400 kg per m^3 (density of silage) = 5.2 m^3 silo pit/animal.

Making/Digging of silo pit: For packing of fresh fodder to prepare silage, stacking, trenching, bunker silos, and plastic bags can be used.

Harvesting and chopping of the crop: The silage prepared from the crop harvested during spring and autumn season has better quality due to having high concentration of protein, sugar and less built up of fibre. The best time for harvesting of maize is at least at stage of 3 or 4 as shown in figure 6.

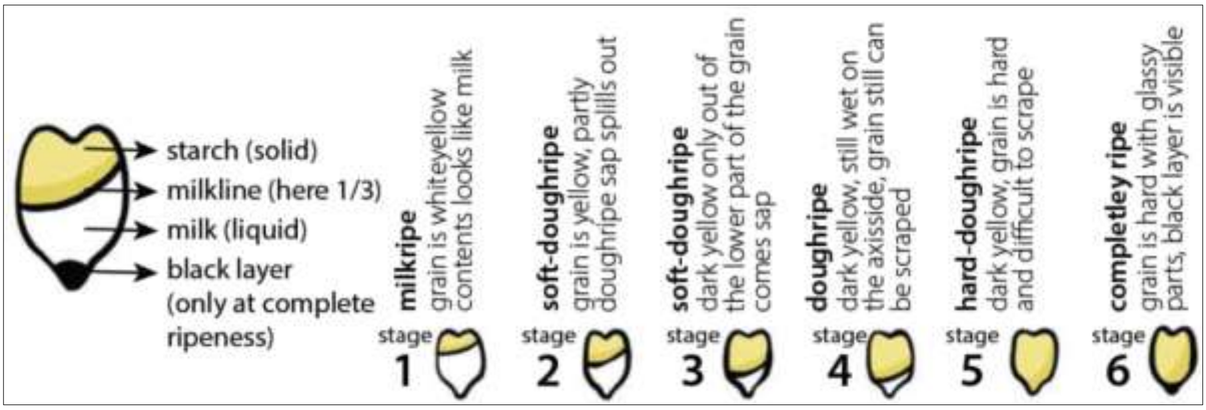

Fig 6: Pictorial depiction of harvesting stage of maize for silage making

Drying of crop to proper moisture level: Drying of crop to optimum moisture content is essential to prepare good quality silage. If the moisture content is too high, it will increase the risk of nutrient losses and the formation of butyric acid leading to a foul smell.
Ball method (figure 7) can be used for checking the moisture content:

- Pick handful of fodder after chopping.
- Press it for 15-25 seconds by making a ball
- After squeezing, release the material as such on your palm.

When you loosen the material, palm should feel a little bit moist. But if water comes out while making/pressing ball or the material fall apart quickly after pressing, it is not fit for packing and sealing. On the other hand, if the material falls apart slowly after pressing and releasing, it can be used for filling the silo pit.

Fig 7: Ball method for checking moisture content in chopped maize for silage making

Filling of silo followed by compaction: While filling of the silo pit with chopped fodder, continuous compaction is required to remove the soft patches and air pockets which otherwise promote the growth of fungus. Sides of the silo pit are important areas that need proper pressing and compaction to prevent entry of air into packed body of silo.

Sealing of silo pit: Immediately after filling and compacting of silo pit (Figure 8), covering becomes need of the hour to make the silo pit airtight material to avoid exposure to air as much as possible. Someone can use plastic sheet of at least 5 mm thickness and keep the plastic sheet in contact with the silage over the entire area. Make sure the plastic does not have holes. Weigh down your silage cover firmly with tyres, bags of sand, mounds of sand or other material placed closely together. Make sure the cover is airtight and watertight, and that there is no air under the cover. After you have covered the silo, monitor it regularly for damage and heating. The temperature of silage should not rise above 40^0C. Overheating can signify that the moisture content is too low, the forage was too mature or too long, or the compacting was insufficient.

Fig 8: A packed silo pit and use of silage opening of silo pit

Table 9: End products of fermentation process of silage making [45]

Parameter	Increase/Decrease	Action
pH	+	Bacterial activity ceases at low pH.
Lactic acid	+	Inhibits bacterial activity by lowering pH
Butyric acid	-	Causes degradation of proteins, formation of toxins and loss of energy
Ethanol	-	Depicts yeast fermentation
Ammonia	-	More amount indicates protein's degeneration
Acid detergent insoluble nitrogen	-	More amount depicts degeneration of proteins due to heat.

QPM and novel foods

Maize is a crop that exhibits genetic variability to a greater extent to have all the quality factors and each quality factor is governed by a number of mutants. This allows for a wide range of potential applications for maize, with the possibility of creating a crop that is tailored to suit the desired needs. In recent years, scientists and researchers across the globe have been making concerted efforts to recognize genes and quantitative trait linkages for different quality traits, which can then be used to bring improved bio-fortified varieties/hybrids. Bio-fortification is a promising approach to addressing malnutrition in the poorest of the poor, but it will be a success only if certain challenges are met. These challenges include providing suitable sale price for the economic product, creating regions of high and good quality productivity, increasing processing of produce, and strengthening delivering system. All of these are necessary to ensure that the technology and products developed reach those who need them the most. This requires investment in infrastructure, such as education, awareness activities, roads, storage facilities, and distribution networks. In addition, biofortification needs to be an inclusive process, involving the participation of all stakeholders like farmers, government, non-governmental organizations, and the private sector.

Besides food, feed and fodder, maize can also be grown for many other purposes, such as quality protein maize (QPM), sweet corn (SC), baby corn (BC), popcorn (PC), waxy corn (WC), high oil (HO), and amylo maize. Two essential amino acids, tryptophan and lysine, are deficient in maize grain, causing consumers to suffer from nutritional deficiencies. Efforts are going on since four decades to develop quality protein maize (QPM). QPM is nutritionally superior having high concentration of above mentioned two essential amino acids. Breeding process to develop quality protein maize is driven by 3 genetic systems *viz*., opaque-2, endosperm modifier and associated gene systems. In normal maize grain, lysine concentration is about 2% of total protein contents. This content of lysine in normal maize grain is less than 50 percent of the amount recommended by FAO. Biological value of normal maize protein is 40-50 percent in contrast to 80 percent that of QPM [46]. As per United Nations Children's Fund (UNICEF), the inclusion of QPM in the daily diet can certainly prove propitious in curbing the menace of malnutrition [47]. Compared to non-QPM products, QPM has higher levels of protein, lysine, and tryptophan [48]. In addition to this, QPM also contains higher concentration of non-zein protein i.e., albumin, globulin and glutelin fractions [49]. Improvisation in the nutritional aspects exploiting traditional as well as modern biotechnological approaches can become promising option to ensure nutritional security. The intake of several micronutrients will increase in order to meet the daily requirements. Baby corn is a young unfertilized cob which is harvested 1-3 days of silk emergence. It is consumed as raw in the form of salad and other recipes like soup, pickles, and Chinese preparations, etc. Waxy corn although originated in China but is largely used in USA. Maize grain has wax like appearance and has 100 percent amylo-pectin starch relative to 30 percent amylose and 70 percent amylopectin in normal maize. Normal maize contain 3- 4 percent oil content and the lines with more than 6 percent oil are classified under high oil corn. High oil corn is utilized by the wet milling industries [50]. Development of specialty corn through scientific approaches can not only improves maize quality but also enhances yield potential. Advancement in maize processing leads to income generation and thereby uplifting the living standard. Therefore, approaches like contract farming of maize, development of infrastructure to promote processing, ensured marketing, collaboration between public and private players can certainly prove fruitful in increasing maize production and productivity.

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