

Improved agrotechniques

for managing abiotic stresses in maize

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Worldwide (including India), maize production suffers significant losses due to abiotic stress conditions like drought, high temperature, cold stress, salinity stress, and excess moisture stress, etc. The maize crop faces tremendous challenges as a result of these stresses, which affect their growth, development and final yield. The adoption agrotechniques such as adjusting sowing time, seeding rate, dry sowing, seed hardening, resource conservation technologies, changing land configuration, balanced nutrient management, improved irrigation management, use of plant growth regulators, antitranspirants, selection of appropriate maize varieties, reclamation of saline and sodic soils have the potential to reduce the effects of abiotic stresses on maize. Therefore, location-specific, need-based appropriate combinations of these agrotechniques can improve maize growth and performance, and eventually yield, bridging the potential and average yield gap under various stress environments.

Keywords: Abiotic stress, Agrotechniques, Drought stress, Heat stress, Maize, Salinity stress

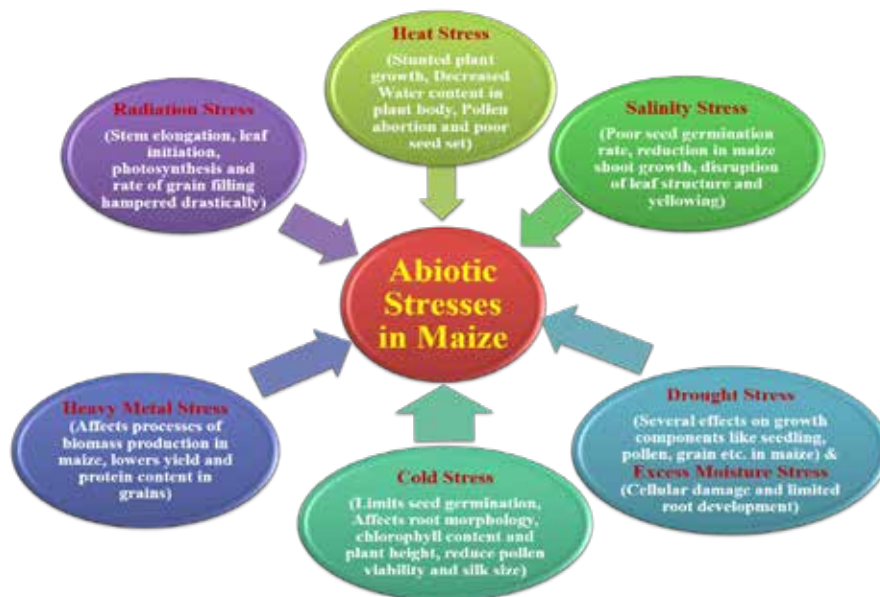
MAIZE is one of the most important cereal crops in the world which contributes in agricultural economy not only as food grain for the population but also as feed for the animals. More than 166 countries grow maize for a variety of purposes, throughout the year, and under a range of agro-ecological conditions. The maize crop, which is also referred to as the “Queen of Cereals” has the largest yield potential of all cereals. While, maize has long been a key source of food on various continents, including Asia, Africa, and Latin America, its output is steadily declining in underdeveloped nations. Such alterations in the production scenario are caused by a few specific problems that exist. Abiotic stresses are one of the key problems among them that affect growth as well as productivity of maize plants. Abiotic stresses like drought, salinity, and heat stress are among the main causes of decreased maize production. Eighty per cent of India’s maize crop is

grown under rainfed conditions, where it frequently experiences abiotic pressures. These stresses are aggravated by climate change, especially those caused by heat and drought. Because of the necessity for better maize cultivation, alleviating abiotic stresses through various

technical interventions need to be followed in a scientific manner.

Effects of temperature stress in maize

Heat stress or high temperature stress: Crop morphological, biochemical, and physiological changes are significantly influenced



Schematic representation of different abiotic stress effects on maize

by heat stress. The principal negative effects of heat stress on maize crops include severe damage to membrane integrity, impaired protein activities, and poor plant quality.

Few of the main effects of heat stress on maize are:

- Maize plants grow in a stunted manner.
- The water content of the plant body drops and transpiration rate increases.
- High temperature causes maize leaves to roll and burn. Drying of leaf margins due to the scorching effect on maize leaves are common symptoms.
- When temperatures is extremely high during silk-tassel stage in maize flowers, pollination is hampered, and grain growth is entirely stopped.

Cold stress or low temperature stress: Common symptoms of low temperature stress on maize leaves include wilting, browning, necrosis of the leaves, and plant death. Chilling and freezing damage can directly affect maize growth, reducing yield by causing physical harm or by interfering with normal biochemical and physiological processes.

The adverse effects of cold stress in maize are as follows:

- Low temperature hampers germination, seedling growth and also disrupts the antioxidant defense mechanism.
- Yellowing and discolouration of maize leaves is seen as a result of the death of leaf tissues from extreme cold. Low temperature stress causes abnormal tassel growth in maize.
- Chilling temperature (0–15°C) can reduce pollen viability and silk size in maize.
- Severe low temperature exposure can cease the grain filling prematurely.

Effects of salinity stress in maize

Salt-affected soils typically have an excess of soluble salts or exchangeable sodium in the root zone of crops. Maize is moderately sensitive to salt stress. Maize's sensitivity to salinity is associated with increased Na⁺ ion accumulation

in the leaves. Sodium is the major toxic ion interfering with K⁺ ion uptake and thus, dismantles stomatal undulations causing severe moisture loss and necrosis in maize.

The major consequences of salinity stress in maize are:

- Yellowing, leaf tip burning and disruption of leaf structures are caused by a decrease in the number of elongating cells or the rate of cell elongation under severe salt stress.
- Reduced stomatal conductance, reduced photosynthetic pigments, impaired activities of carbon fixation enzymes, and photosynthetic apparatus destruction are among major factors limiting the maize plant's carbon fixation capacity under salt stress.
- Salt stress in maize during reproductive growth stage reduces grain number and weight, resulting in significant yield reductions in maize.

Effects of drought stress in maize

Maize is a drought-prone crop. Drought affects maize at various stages of development in different parts of the world. Drought stress has a serious impact on the maize productivity. The negative effects of drought stress in maize are described in Table 1.

Effects of excess moisture in maize

Excess moisture in crop field is the result of high water table and drainage problem. Excessive soil moisture caused by flooding, waterlogging, or a high water table is one of the most significant constraints

to Asian maize production and productivity. The major Indian states with excess moisture stress in crop fields are Uttar Pradesh (East), Bihar, Jharkhand, West Bengal, and Odisha. The seedling, knee high and flowering stages of maize are more prone to excess moisture stress. The root respiration process of maize in flooded soil is hampered within 48 hours due to a lack of oxygen supply, which eventually leads to membrane impermeability. If this condition persists for an extended period of time and the ambient temperature exceeds 25°C, it may result in plant mortality.

Agro-techniques for managing drought and high temperature stress

Selection of appropriate varieties: Growing of maize varieties tolerant to drought and high temperature can ensure high yield and good returns. Some of the important tolerant maize varieties are high temperature tolerant such as Buland, PMH 1, PMH 3 etc and drought tolerant, e.g. Pusa Hybrid Makka 1, HM 4, Pusa Hybrid Makka 5, DHM 121 and Buland variety.

Improved nutrient management: Potassium application improves drought resistance and water-use efficiency by improving the water uptake and water relations in plant tissues via the osmoregulation process. Micronutrient deficiencies such as Zn, B, and Fe aggravate water deficit stress, and their balanced application helps in mitigating maize water stress. Foliar applications of 2% DAP, 0.5–1% potassium chloride, 0.5–1% ferrous

Table 1. Adverse effects of drought on different growth components in maize crop

Growth components and stages of maize	Impact of drought stress
Germination stage	Reduces germination potential by reducing seed viability, poor imbibition and poor performance post germination
Seedling stage	Poor crop stand or complete failure of seedling establishment due to lack of moisture
Pollen development	Settling speed, pollen viability, pollen shape and dispersal are drastically affected when the pollens are dehydrated due to lack of moisture
Silk development	Silking is delayed by 6–9 days by the prevalence of drought stress
Grain production	Grain filling is reduced due to decreased activity of sucrose and starch synthesizing enzymes under drought stress condition

sulphate, and 1% urea, depending on the occurrence of their deficiencies has been reported to mitigate the water stress-induced nutritional imbalance in maize. To reduce plant stress, split N application and the use of biofertilizers such as *Azotobacter* and phospho-bacteria may also be recommended.

Use of anti-transpirants and plant-growth regulators: Anti-transpirants can be used effectively on the maize crop in drought conditions with low rainfall. Anti-transpirants are classified according to their mode of action such as stomata closure (PMA, Atrazine, TIBA), reflectant (Kaoline, China clay, Lime water), film forming (higher alcohols such as Hexadecanol, Cetyl alcohol, and thick film forming commercial polythene materials such as Mobileaf, Folicot, and Waxol) etc. Some plant growth regulators (PGR) such as Cycocel, Mepiquat chloride, Cytokinins, Salicylic acids and Ascorbic acid are also beneficial when growing maize in water-stressed and high temperature

conditions.

Pre-sowing hardening/priming of seeds: Seed priming is a method of partially dehydrating seeds so that germination-related metabolic processes begin but radicle emergence does not occur. Priming hardens the protoplasm through osmoregulation, which aids in the preservation of germination percentage and ensures seed viability under high temperature and drought stressed conditions. Application of KH_2PO_4 (1%), KCl (1%), Succinic acid (100 ppm), ZnSO_4 (100 ppm), NaCl (0.5%), Cycocel (250 ppm) etc. are used for maize seed hardening.

Soil and water conservation: To lessen the effects of drought and high temperature stress, it's important to conserve soil and water through techniques like stubble mulch tillage, zero-tillage, conservation agriculture, mulching, changing land configurations like ridge and furrow, permanent bed, broad-bed and furrow, tied ridging, scooping, and laser leveling, maintaining an ideal plant population and water harvesting.

Adjusting sowing time: To deal with the issue of high temperatures and drought stress, choosing an appropriate sowing time is crucial. Maize seedling and reproductive phases (tasseling and silking) are more sensitive, so the sowing date can be chosen to avoid these phases to fall during moisture stress period. In rainfed situation, pre-monsoon sowing or dry sowing of maize seeds is advised 10 days prior to the start of the monsoon. Farmers should avoid planting conventional long-duration maize varieties during a delayed monsoon. For example, the variety Punjab Sathi-1 is one of the most suitable varieties during summer in north-west India as it is heat tolerant and matures in 70 days.

Methods and time of irrigation: At flowering and grain development stages, maize shouldn't be under moisture stress because it could cause pollen to dry out, resulting in poor fertilization and grain filling. Supplemental irrigation can be used in the event of an unexpected drought condition to save the crop. Irrigation can be applied in alternate furrows under conditions of low water availability without having a significant negative impact on crop productivity. In rainfed areas, tied ridges are helpful in conserving the rain water. In areas with high temperatures and scarce water supplies, microirrigations, particularly surface and sub-surface drip irrigation, are gaining popularity.

Effective weed management: Weeds compete with crops for limited water. Effective control of weeds ensures more water supply to crops, and helps the crop to escape the drought.



Cultivation of maize on permanent bed (PB) conserves soil moisture and improves crop performance



Zero-tillage (ZT) based maize systems are more resilient to soil moisture stress than conventionally-tilled (CT)

Agro-techniques for managing low temperature stress

Alteration of date of sowing: Delayed sowing of winter maize beyond mid-November in north-western India, results in poor germination and lower yield due to very cold conditions while, in eastern and southern India, delayed sowing results in lower yields due to shortening of the growing season.

Irrigation: Light and tactical



Sub-surface drip fertigation in maize for improved nutrient and water management under drought, high temperature condition

application of irrigation may also aid to alleviate the adverse effects of low temperature/chilling stress in maize. Irrigated soil has a significantly higher heat capacity than dry soil. It is always recommended to irrigate the field frequently in the evening during cold spells. During the early stages of crop growth, overhead water application at evening/night may be used to protect maize from low temperature/chilling stress or frost damage.

Nutrient management: Higher level of nitrogen application increases cool temperature susceptibility. Application of adequate amount of phosphorous, potassium and farmyard manure increases the tolerance of maize to low temperature. Foliar spray of 0.15% ammonium molybdate may be advocated to reduce low temperature induced sterility.

Agro-techniques for management of salinity stress

Better crop establishment: In saline soil, poor maize germination is a common problem. In most cases, a 25% increase in the seed rate ensures good crop stand. Planting on the side of the ridge halfway between top and bottom, opposite to the sun direction may help to get good maize stand in saline soils as salt accumulates on the ridges.

Soil fertility and water management: To ensure stable maize yield under saline soils, judicious application of bulky organic manure and chemical fertilizers, a higher dose (25% extra) of N over normal

soils, and its split applications are recommended. Under saline soils, foliar application of N is also advised. A foliar spray of 2% DAP + 1% KCl (MOP) during critical stages can be very effective. Since most sodic soils typically lack zinc (Zn), applying Zn @25 kg $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$ or 15 kg of $\text{ZnSO}_4 \cdot \text{H}_2\text{O}$ at sowing is necessary to increase productivity. A mixture of zinc sulphate and lime @3 kg $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$ + 1 kg unslaked lime with 500 litres of water/ha should be sprayed when symptoms are seen in the later stages of crop growth. During crop seasons, irrigation should be light and frequent with just one or two deep irrigations to maintain a low osmotic potential.

Biological reclamation: For salt-affected soil improvement, application of biological materials (FYM, compost, green manure, vermicompost, crop residue, stubble mulching, etc) are recommended. These organic materials release carbon dioxide, acids and acid-forming materials, which convert insoluble calcium to soluble form and thus, replace sodium from soil exchangeable sites.



In situ stubble mulching helps to mitigate salinity stress in maize

Chemical reclamation and leaching: Gypsum is the most commonly used amendment for sodic soil reclamation, which is needed to be applied @10–15 t/ha (having 70% purity) for reclaiming 15 cm soil layer. Other amendments that can be used include pyrites, iron sulphate and calcium chloride etc. Saline soils, on the other hand, do not require any amendments. The ultimate reclamation of salt-affected soil involves the removal of salts through leaching with water.

Agro-techniques for management of excess moisture stress

Excess water is drained out by making a drain of adequate capacity at the lower end of the field. If damage occurs due to water logging, 2–3 sprays of 3% urea solution at weekly interval may be applied. Additional application of 30–40 kg N/ha is also recommended after the flooding is over to mitigate the flood damage.

SUMMARY

Drought, high temperatures, cold stress, salinity stress, and excess moisture stress all cause significant losses in maize production. Adoption of location specific need-based combinations of agro-techniques such as adjusting sowing time, using high seed rate, dry sowing, seed hardening, resource conservation technologies, changing land configuration, balanced nutrient management, improved irrigation, use of plant growth regulators, antitranspirants, selection of appropriate maize varieties, reclamation of saline and sodic soils have potential to reduce the effects of abiotic stresses on maize crop growth and development, and ultimately yield, and thus bridge the potential-average yield gap under various stress environments. There is an urgent need to strengthen crop improvement programmes in order to develop improved crop varieties with multiple resistances to various abiotic stresses.

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