Abiotic Stresses And Its Management In Agriculture

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Introduction

In today's climate change sceranios, crops are exposed more frequently to episodes of abiotic stresses such as drought, salinity, elevated temperature, submergence and nutrient deficiencies. These stresses limit crop production. In recent years, advances in physiology, molecular biology and genetics have greatly improved our understanding of crops response to these stresses and the basis of varietal differences in tolerance. This chapter will clearly define the different abiotic stresses and their impacts on agricultural productivity.

Stress – Definitions

(i) Physical terms

Stress is defined as the force per unit area acting upon a material, inducing strain and leading to dimensional change. More generally, it is used to describe the impact of adverse forces, and this is how it is usually applied to biological systems.

(ii) Biological terms

In the widest biological sense, stress can be any factor that may produce an adverse effect in individual organisms, populations or communities. Stress is also defined as the overpowering pressure that affects the normal functions of individual life or the conditions in which plants are prevented from fully expressing their genetic potential for growth, development and reproduction (Levitt, 1980; Ernst, 1993).

(iii) Agricultural terms

Stress is defined as a phenomenon that limits crop productivity or destroys biomass (Grime, 1979).

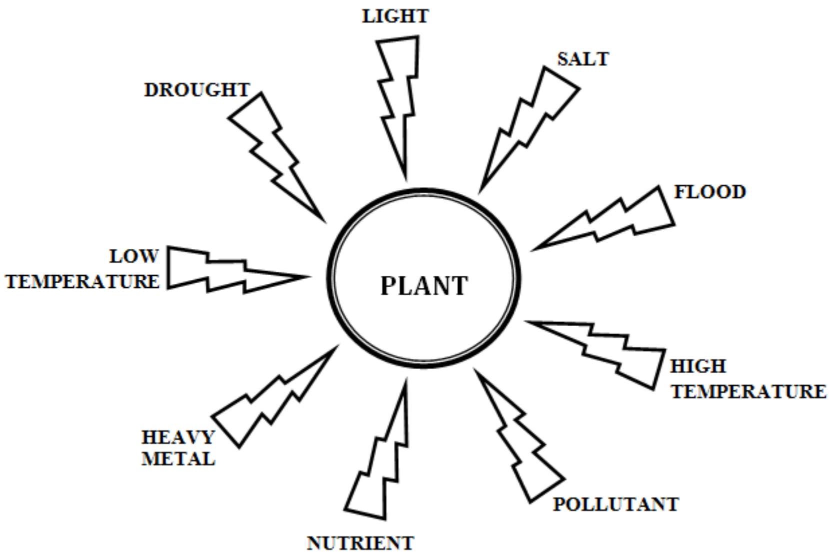
Classification Of Stresses

It has become traditional for ecologists, physiologists, and agronomists to divide stresses experienced by plants into two major categories: biotic and abiotic. Biotic stresses originate through interactions between organisms, while abiotic stresses are those that depend on the interaction between organisms and the physical environment. Strictly speaking, biotic stresses result from competition between organisms for resources, from predation and parasitism, and from the actions of allelopathic chemicals released by one organism and affecting another.

Abiotic Stress

Abiotic stress management is one of the most important challenges facing agriculture. Abiotic stress can persistently limit choice of crops and agricultural production over large areas and extreme events can lead to total crop failures. Abiotic stresses adversely affect the livelihoods of individual farmers and their families as well as national economies and food security.

Abiotic stresses include potentially adverse effects of Salinity, Drought, Flooding, Metal toxicity, Nutrient deficiency, High temperature and Low temperature. In addition, abiotic stresses can include Shade, UV exposurePhotoinhibition, Air pollution, Wind, Hail and Gaseous deficiency which are often sporadic and highly localized in occurrence.



Common abiotic stresses in plants

Plants can experience abiotic stress resulting from the shortage of an essential resource or from the presence of high concentrations of a toxic or antagonistic substance. In some cases, such as the supply of water, too little (drought) or too much (flooding) can both impose stress on plants. In reality, abiotic and biotic stresses are often inextricably linked.

Major Abiotic Stresses Limiting Crop Yield

Drought

Among the environmental stress factors, one of the most widely limiting for crop production on a global basis is water. According to one estimate, around 28 percent of the world's land is too dry to support vegetation (Kramer and Boyer, 1995). On a global basis, water is a paramount factor in determining the distribution of species, and the responses and adaptation of species to water stress are critical for their success in any environmental niche and for their use and productivity in agricultural ecosystems. Severe droughts occur periodically in several major food-producing countries, having far-reaching impacts on global food production and supply. The global production of grain has, in some years, been reduced by 5 percent or more as a result of severe droughts in key countries. It has been estimated that drought causes an average annual yield loss of 17 percent in the tropics (Edmeades et al., 1992), but losses can be much more severe and total crop failures are not unknown.

Definitions:

Drought can be defined as an extended period of deficient rainfall relative to the statistical mean for a region.

Meteorological drought is qualified by any significant deficit of precipitation.

Hydrological drought is manifest in noticeably reduced river and stream flow and critically low groundwater tables.

Agricultural drought: indicates an extended dry period that results in crop stress and crop yield. The impact of drought on agriculture is due to a deficit of moisture in the soil, when the moisture in the soil is no longer sufficient to meet the needs of growing crops. This results from a lack of input of moisture from rainfall or irrigation for an extended period. It is impossible to specify a period of time without rain as an agricultural drought, as the soil moisture deficit depends on rate of loss as well as rate of input. Furthermore, the severity of stress imposed on crops also depends on the susceptibility of different crops during different stages of their development. When soil moisture is lacking, crop establishment may be reduced, growth limited, normal development patterns disrupted and eventually, final yields lowered.

Effects of drought stress on crops

· Reduced seed germination and seedling development

· Poor vegetative growth

· Reproductive growth is severely affected

· Plant height and leaf area reduced

· Significantly reduction in leaf weight

· Reduced photosynthesis.

· Reduced stomatal conductance

Significantly reduction in the total dry matter (Fig.1)

Recent droughts in Tamil Nadu

For three consecutive years 2012 and 2013, 2014 the state has been reeling under drought, having received below normal rainfall. During 2012 Tamil Nadu received 245.7mm of rain during the southwest monsoon between June and September. Last year it was 24% less than the average of 321.2 mm. The northeast monsoon also failed.

Crop damage due to droughts

Drought has not only affected crop husbandry adversely, but has also upset rural livelihoods in Tamil Nadu. For want of fodder, cattle grazers had to take the unusual step of cutting palmyra leaves to feed their animals. Surprisingly, even these sturdy, deep-rooted and drought-resistant trees have been withering. Around 7,000 thirty-year-old Palmyra trees have completely withered due to drought in Konganapuram and Edapaddy blocks in Salem district in the last one year. In these areas tree climbers (toddy tappers) and

tree owners of these groves have been left with nothing, and the livelihood of palm leaf basket and mat weavers and palm sugar makers (majority are women) has been affected. Unlike coconut palms, Palmyra do not have crop insurance cover.

Areca nut, another perennial crop, is also under threat in the villages of Attur taluk–Thammampatti, Veeraganur, and Ulipuram–in the drought prone district of Salem. This taluk is known for cultivating cash crops like betel wine, papaya, areca nut and sugarcane, as this region is endowed with rich fertile soil and abundant groundwater. Located at the foot of Servarayan hills, this area has been ravaged by drought. Due to poor rainfall in the last two years, the ground water table has been receding and wells have been drying up in the area as revealed by local progressive farmers. Areca plantations and papaya gardens have been withering in the area for want of water during this summer (2014). About 50,000 saplings of the high-yielding variety of "red lady" papaya, grown on 230 acres in Pethanaickkanpalayam, Manivizhundhan and Kallanatham clusters in Salem district and neighbouring areas, have already withered this year. To irrigate their crops, farmers installed subsidised drip irrigation systems, but the availability of water was insufficient to operate them.

Mitigation of Drought Stress

1. Foliar spray of 2% DAP + 1% KCl during critical stages of flowering and grain formation
2. 3% Kaoline spray at critical stages of moisture stress
3. Foliar spray of 500 ppm Cycocel (1 ml of commercial product per litre of water)

Mulching with 5 tonnes of sorghum / sugarcane trash, which saves 19-

1. 20% of irrigation water by reducing evaporation loss of water

2. Split application of N and K fertilizers as in cotton at 45 and 60 DAS

3. Use of biofertilizers *viz.*, Azospirillum or Phosphobacteria @ 10 packets / ha along with 25 kg of soil or FYM.

4. Seed hardening with 1% KH_2PO_4 and other salts for 6 – 8 hours (depending upon nature of seed coat) soaked in equal volume of water

5. Spray of 40 ppm NAA (4 ml of Planofix in 4.5 litres of water)

6. Seed treatment + soil application + foliar spray of Pink Pigmented Facultative Methnaotrops (PPFM) @ 106 as a source of cytokinins.

7. In cotton, nipping terminal portion of main stem beyond 15th node (at 70 - 80 DAS) and at 20th node (at 90 DAS) in the case of hybrids and varieties respectively for arresting transpiration loss of water)

8. Foliar spray of 0.5% zinc sulphate + 0.3 % boric acid + 0.5 % Ferrous sulphate + 1% urea during critical stages of moisture stress

Application of PGRs namely Cytokinin (10 ppm); Brassinolide (0.5 ppm); Salicylic acid (100 ppm); Ascorbic acid (100 ppm) and CCC (10 ppm).

Flooding stress

Definition: Flooding may be defined as any situation of excess water. Sudden inundation following high rainfall events also poses a severe physiological stress on crops. The gradual inundation of crop lands that occurs in a more regular cycle of seasonal changes in river levels and associated gradual flooding of crop lands poses a different, but equally challenging, flooding environment to which plants must adapt. As a result, some plants, such as rice, evolve a semiaquatic habit. Flooding stress in terrestrial species is referred to as waterlogging and the damage symptoms caused are primarily due to the prolonged exposure of the plants to hypoxia. The effect of waterlogging of roots and lower stems are apparent as a range of symptoms on the shoots, including rapid wilting and severe physiological disruption. Vast areas of rainfed crops, particularly in South and Southeast Asia, are annually affected by flooding.

Types of floods

Flooding can be catastrophic, with flash floods causing major soil erosion and direct physical destruction of crops. There are two typical kinds of flood. One is short duration over a few weeks and not very deep, termed a '**flash flood**' and the other is deep flooding that lasts for a long time, called as '**deepwater flood**'. Flash floods are unexpected and uncontrollable, and its flooding water level can reach 50 cm in the rainfed lowlands of the humid and semihumid tropics of South and Southeast Asia. In these areas, flash floods at the seedling stage of rice cause severely reduced yields of rice grain (Hattori *et al*., 2011) (Fig.2)

Floods in Tamil Nadu and Crop Damage due to floods

Heavy rainfall due to the cyclone named "NISHA" has flooded many low-lying areas in Cuddalore, Thiruvarur, Chithambaram, Karur and neighbouring areas. Thanjavur district is benefited more by North-East monsoon because of its heavy rainfall and the Western Ghats in variable feeds the Cauvery and helps greatly for the vast cultivation of the deltaic area. The floods in the **Deltaic region** of the Thiruvarur, Nagapattinam and Thanjavur region damage the agricultural crops. Standing paddy crop on the Cauvery delta region is estimated to have been damaged heavily due to rainfall amounting to 111.37mm average in the rainy season. Some places have recorded extreme rainfall, notably Orathanadu, Thanjavur District where over 660 mm of rain fell within a period of 24 hours and broke the 65-year old record of highest rainfall registered in 24 hours in Tamilnadu. In two days, Orathanadu registered 990 mm of rainfall. The prominent crops raised in this district are food crops chiefly Paddy, Pulses Groundnut, Onion, Sugarcane and Cotton

Effects of flooding stress on plants

1. Decay and death of leaves
2. Wilting
3. Abscission
4. Epinasty
5. Lenticels formation

Nutrient deficiency & Toxicity: Under the anaerobic condition Fe toxicity is high. This leads to increase the polyphenol oxidase activity, leading to the production of oxidized polyphenols. It also causes leaf bronzing and reduced root oxidation power.

Iron toxicity symptoms:

¨ Tiny brown spots on lower leaves starting from tip and spread toward the leaf base or whole leaf colored orange yellow to brown

¨ Spots combine on leaf interveins and leaves turn orange brown and die.

¨ Leaves narrow but often remain green.

¨ In some varieties, leaf tips become orange yellow and dry up.

¨ Leaves appear purple brown if Fe toxicity is severe.

¨ Stunted growth, extremely limited tillering.

¨ Coarse, sparse, damaged root system with a dark brown to black coating on the root surface and many dead roots.

¨ Freshly uprooted rice hills often have poor root systems with many black roots. (Fig.3)

Mitigation of flooding stress

1. Providing adequate drainage for draining excessive stagnating water around the root system.
2. Spray of growth retardant of 500 ppm cycocel for arresting apical dominance and thereby promoting growth of laterals.
3. Foliar spray of 2% DAP + 1% KCl (MOP).
4. Spray of 0.5 ppm brassinolide for increasing photosynthetic activity.
5. Foliar spray of 100 ppm salicylic acid for increasing stem reserve utilization under high moisture stress.
6. Foliar spray of 0.3 % Boric acid + 0.5 % $ZnSO_4$ + 0.5 % $FeSO_4$ + 1.0 % urea during critical stages of the stress .
7. Balance the use of fertilizers (NPK or NPK + lime).
8. Apply sufficient K fertilizer.

Apply lime on acid soils, do not apply excessive amounts of organic matter (manure, straw) on soils containing large amounts of Fe and organic matter.

Salinity stress

One of the most common forms of land degradation results from soil salinization. Almost all of the continents have saline soils. However, salinity is predominantly a problem of arid and semiarid regions of the world, where the potential for evapotranspiration exceeds rainfall and there is insufficient rain to leach away soluble salts from the root zone (Miller and Donahue, 1990). In India alone, 7 million hectares of land are salt affected. Tamil Nadu, which is one of the strong rice cultivation areas in India, are prone to salinity stress. The impact of salinity on the economic exploitation of land for agriculture and forestry is very severe (Singh and Singh,1995). According to an early Food and Agriculture Organization (FAO) study (Massoud, 1974), salt-affected soils occupy 7 percent of the world land area, and salinity is also a problem that is increasing rapidly (Pessarakli, 1999), having more than doubled in the past two decades. It is estimated that the world is losing at least 10 ha of arable land every minute and 3 ha of this is lost by salinization. In this way, 1.6 mha of arable land is lost every year. Secondary salinization is widely considered a key process leading to degradation and desertification of the world's dry lands. Ironically, much of the loss of land due to salinization is in fact caused by agriculture itself through the adverse effects of irrigation, this occurring in up to 20 percent of irrigated land (Flowers and Yeo, 1995). The ability of plants to survive salinity stress is important for natural distribution of plant species and to agriculture (Flowers and Yeo, 1989).

Definition

Salinity is defined as the presence of excessive amounts of soluble salts that hinder or affect the normal functions of plant growth. It is measured in terms of electrical conductivity (ECe), with the exchangeable sodium percentage (ESP) or sodium adsorption ratio (SAR) and pH of a saturated soil paste extract. Therefore, **saline soils** are those that have saturated soil paste extracts with an ECe of more than 4 dSm^{-1}, ESP less than 15 percent, and pH below 8.5 (Waisel, 1972; Abrol, 1986; Szabolcs, 1994). Saline soils have a mixture of salts of Chloride, Sulfate, Sodium, Magnesium and Calcium ions with sodium chloride often dominant.

There are two main sources of salinity:

(i) Primary or natural sources

Resulting from weathering of minerals and the soils developed/derived from saline parent rocks

(Ashraf, 1994)

(ii) Secondary salinization

Caused by human factors such as irrigation, deforestation, overgrazing, or intensive cropping (Ashraf, 1994).

Salinization affects the

1. Chemical properties of soil by changing the cation exchange capacity (CEC)
2. Alter the physical properties: Soil structure is damaged by defloculation of clay particles and hydraulic conductivity is decreased, resulting in a slow movement of irrigation water.
3. Soil salinity also affects the soil microflora that plays important roles in the improvement of soil structure, the decomposition of organic matter and the nitrogen and sulfur cycles (Lal and Khanna, 1994).

Salt stress in Tamil Nadu

The coastal soils are affected by salinity due to sea water intrusion. The special and problem areas are Peravurani, Sethubavachatram, Adirampattinam and other coastal areas. These soils contain sufficient soluble salts (chlorides and sulphates of Ca, Mg and Na) in the root zone and adversely affect the crop growth. The factors contributing for salinisation are high salt content in the profile, saline ground water, occurrence of salt layer, seepage from canals and higher adjacent areas, poor surface and subsurface drainage, saline irrigation water, industrial effluents and sea water intrusion. Trichirappalli district of Tamil Nadu, has 21,404 ha of total geographical area Out of this, about 3,667 ha is declared as salt affected based on the soil pH value. About 1167 ha is strongly affected by salts with a pH of 9.2 to 10.3. Farmers in this region grow paddy in rainy season and keep the land fallow during remaining months of the year. Rarely, they raise daincha crop during South West monsoon.

Effects of salt stress on plants

Effects of salt stress on plants

1. Osmotic effect or water deficit effect: Reduces the plant's ability to take up water, and this leads to slower growth. This is the osmotic or water-deficit effect of salinity.
2. Salt specific effect or Ion Excess Effect: Salts enter the transpiration stream and eventually injure cells in the transpiring leaves, further reducing growth. (Fig.4)

· Plants grown in alkaline soils often display a characteristic yellow color on the new growth. Veins remain green, and the yellow color develops between veins. Severe deficiency may cause leaves to be almost white. Deficiencies of other micronutrients such as zinc and copper may produce a similar condition in peanuts. Chemical analysis of the plant tissue is the only sure way to differentiate.

· High salts can cause leaf burn, inhibit water uptake, and can interfere with uptake of certain essential elements (e.g., calcium).

· Stress at reproductive stages leads to spikelet sterility in cause of rice.

· Accumulation of Na^+ and Cl^- is toxic to cell in terms of the effect in enzyme activity.

Mitigation of salt stress

· Seed hardening with NaCl (10 mM concentration)

·Application of gypsum @ 50% Gypsum Requirement (GR)

· Incorporation of daincha (6.25 t/ha) in soil before planting

· Foliar spray of 0.5 ppm brassinolode for increasing photosynthetic activity

· Foliar spray of 2% DAP + 1% KCl (MOP) during critical stages

· Spray of 100 ppm salicylic acid

· Spray of 40 ppm of NAA for arresting pre-mature fall of flowers / buds / fruits

· Extra dose of nitrogen (25%) in excess of the recommended

· Split application of N and K fertilizers

· Foliar application of ascorbic acid alone increased number of leaves and leaf area, while in combination with zinc sulfate increased the plant height and total plant biomass.

· The exogenous application of PGRs, auxins ,gibberellins and cytokinins produces some benefit in alleviating the adverse effects of salt stress and also improves germination, growth, development and seed yields and yield quality

· Exogenous application of ABA reduces the release of ethylene and leaf abscission under salt stress in plants, probably by decreasing the accumulation of toxic Cl^- ions in leaves.

· Post-application with exogenous Jasmonic Acid can ameliorate salt stress, especially the salt-sensitive rather than the salt-tolerant cultivar. 4 mM ascorbic acid and 4 mM gibberellin could increase transpiration rate, relative water content, chlorophyll *b*, total chlorophyll and xanthophyll content. In general, it was concluded that synergistic interaction between ascorbic and gibberellin could alleviate the adverse

· effects of salinity on plants.

· Maintenance of high K/Na ratio by applying potash and Ca' fertilization

· Application of PGRs like cytokinin,GA_3, IAA, cycocel, thiourea and polyamines (putrescine, spermidine and spermine) either as seed treatment or foliar spray

Temperature stress:

Definition

Greaves (1996) defines suboptimal temperature stress as any reduction in growth or induced metabolic, cellular or tissue injury that results in limitations to the genetically determined yield potential, caused as a direct result of exposure to temperatures above or below the thermal thresholds for optimal biochemical and physiological activity or morphological development.

High Temperature Stress

Levitt (1980) classified plants into psychrophiles, mesophiles, and thermophiles according to whether or not they tolerate low, medium, or high temperatures. Psychrophiles are those plants whose high temperature threshold is 15 to 20°C, mesophiles are those plants whose high temperature threshold is 35 to 45°C, and thermophiles are those plants whose high temperature threshold ranges from 45 to 100°C. Levitt (1980) proposed that the high temperature injury process progresses from a direct reversible strain, i.e., excess respiration over photosynthesis due to elevated temperatures, to an indirect strain, i.e., loss of reserves, or to a direct or indirect injury, i.e., starvation injury. High temperatures may be experienced by plants on a daily or seasonal basis. There is also growing evidence of long-term climatic changes leading to both higher average temperatures, widening the geographic range where high temperatures become routinely limiting to crop production, and increasing the frequency and severity of extreme temperature events. Plants may be as affected by exposure to prolonged periods of moderately high temperature as to short periods of extreme temperature, though the mechanisms for coping with these stresses may differ. Heat stress affects grain quality and yield.

Low Temperature Stress

Low temperatures can damage plants both by a chilling effect, leading to physiological and developmental abnormalities, and by freezing, causing cellular damage directly or via cellular dehydration. Lyons (1973) described many symptoms of low-temperature injury. Some physiological processes such as flowering in rice are extremely sensitive to low temperatures and damage may occur at temperatures as high as 20°C. Commonly visible symptoms of low-temperature injury to the leaves include wilting, bleaching due to photooxidation of pigments, waterlogging of the intercellular spaces, browning, and eventually leaf necrosis and plant death (Levitt, 1980; Witt and Barfield,1982). Dudal (1976) estimated that 15 percent of arable land is

affected by freezing stress. Low temperatures can reduce crop yields in several ways. Chilling and freezing injury can directly affect crop growth by causing physical damage or by interfering with normal biochemical and physiological functions, thus reducing yield. More subtly, low temperatures reduce potential agricultural productivity by limiting the crops or varieties that can be grown in a particular area, with cold-tolerant species/cultivars often not those with the highest potential yield. Low-temperature exposure can be both a daily and seasonal factor to which plants must adapt, including, in some regions, prolonged periods of low temperature lasting many months.

Effects of Heat stress on Plants

¨ Seedling establishment is hampered

¨ Drying of leaf margins and scorching effect on leaves

¨ Reduction in plant growth

¨ Pollen development is affected

¨ Alteration in photosynthesis

¨ Total biomass is reduced

¨ Spikelet sterility

¨ Grain and fruit development and quality is affected (Fig.5)

High Temperature stress in Tamil Nadu

Tamil Nadu can be divided broadly into two natural divisions (a) the coastal plains and (b) the hilly western areas. The average temperature in the hilly areas varies between a minimum of 21.3^{o}C to a maximum of 35.9^{o}C. The average temperature in the plains varies between a minimum of 10.5^{o}C to 24.9^{o}C. In general, the maximum temperature rarely exceeds 43° C and the minimum temperature rarely downs below 18° C. The mean annual

Mitigation of high temperature stress

- Plants need to be cultivated under shade condition.
- Overhead irrigation to avoid sunburn.

- Application of Gibberellic Acid Stimulate the α - Amylase production for seed germination.
- BAP reduce the leaf senescence & Lipid peroxidation .
- Salicylic acid enhances the Thermo tolerance capacity.
- Glycine betaine reduced the leakage of ion.
- Application of Ethylene enhance the seed germination

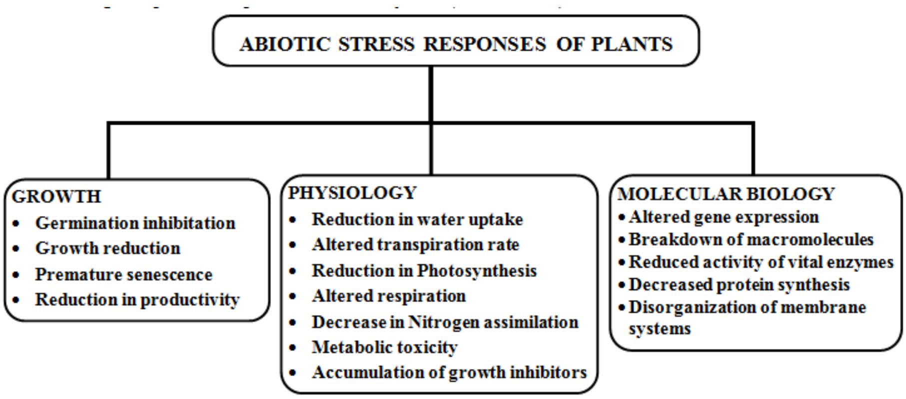
Mitigation of low temperature stress

- Foliar spray of 0.15 % Ammonium molybdate reduces the low temperature stress effect.
- Pre-soaking treatment with GA_3 and Proline increase the Seed germination.
- Application of Paclobutrazol increases the activity of Scavenging enzymes.
- Electrolyte leakage is reduced by the application of Uniconzole (50 ppm).
- Cryoprotectants also used for reducing the stress effect.
- ABA has a role in induction of freezing tolerance.

Summary of Abiotic Stress Responses

With a wide range of abiotic stresses able to adversely affect plants through a multitude of mechanisms, there are no universal symptoms of stress and it is sometimes, as with certain mineral deficiencies, possible to use the visible symptoms of stress to discern the cause. The symptoms of stress, of course, vary with its severity, from the subtle to the catastrophic. Taking a wide ecological perspective, the symptoms of stress have previously been grouped into the following categories

1. Invisible but measurable injuries, e.g., change in biomembranes or enzyme activities
2. Visible injury of plant parts, e.g., necrosis, chlorosis, and discoloration
3. Retarded growth, development, and reproduction
4. Changes in the interference caused by heterotrophs
5. Changes in the genotypes of which populations are composed and
6. Change in species composition of an ecosystem (Lerner, 1999)



Crop varieties evolved with improved abiotic stress tolerance in Cereals

S.No	Rie Varieties	Type of stress	Region of cultivation
1.	PMK1	Drought and High Temperature	Ramanathapuram Sivagangai, Pudukkottai,Madurai, Theni, Dindigul, Virudhunagar,Erode
2.	PMK2		
3.	PMK3		
4.	Anna 4		
5.	RMD1		
6.	MDU5		
7.	Co 43	Salinity	Tiruvarur, Thanjavur, Nagapattinam, Pudukkottai, Ramanadhapuram, Kanyakumari, Kanchipuram, Cuddalore Trichy, Coimbatore, Erode
8.	TRY 1		
9.	TRY 2		
10	CORH 2		
11.	RMD1		
12	CR1009 Sub 1	Flood and Submergence tolerance	Tiruvarur, Thanjavur, Nagapattinam, Pudukkottai,Kanchivaram Ramanadhapuram, Kanyakumari,

13	MDU 3	Low temperature	Madurai, Dindigul, Theni

Crop varieties evolved with improved abiotic stress tolerance in Pulses

S.No	Variety	Type of stress	Region of cultivation
1.	**Green gram** Paiyur 1	Drought	Ramnad, Pudukkotai, Tirunelvei, Vellore, Tiruvannamalai, Tuticorin, Madurai, Trichy
2.	Co 6		
3.	ADT 3	Salt stress	Cauvery delta regions
4.	ADT 3	Flooding/Submergence	Cauvery delta regions
5.	**Black gram** VBN 6	Drought	Ramnad, Pudukkotai, Tirunelvei, Vellore, Tiruvannamalai, Tuticorin, Madurai, Trichy
6.	VBN 3	Drought	Entire Tamilnadu
7.	ADT 3	Flooding/Submergence	Regions around Kanyakumari
8.	ADT 5	Flooding/Submergence	High rainfall regions

9.	**Cowpea** Co 6	Drought	Coimbatore, Salem, Erode, Dharmapuri, Vellore and Thiruvannamalai
10	VBN 1	Drought	Pudukottai, Trichy, Madurai, Vellore and Thiruvannamalai
11.	VBN 2	Drought	Entire Tamilnadu
12	CO (CP) 7	Flooding/Submergence	Cauvery delta regions
13.	**Redgram** Co 6	Drought	Thiruvannamalai, Salem, Dharmapuri, Coimbatore, Erode
14.	Vamban 2	Drought	Ramnad, Pudukkottai, Tirunelveli, Vellore, Tiruvannamalai, Tuticorin, Madurai, Trichy
15.	Co 5	Salinity	Thanjavur, Trichy and Pudukkottai
16.	**Bengal gram** Co 3	Drought	Coimbatore, Salem, Dhramapuri
17.	Co 4		
18.	Co 5	Salinity	Coimbatore, Salem, Erode, Dharmapuri and Vellore

19.	**Soyabean** Co 1	Drought	Entire Tamilnadu
20.	Co 2		
21.	ADT 1	Salinity	Suited to Tanjore, Tiruvarur, Nagapattinam, Cuddalore and Trichy
22.	**Horse gram** PAIYUR 1	Cold/Frost	The Nilgris and Kanyakumari
23.	PAIYUR 2		

Crop varieties evolved with improved abiotic stress tolerance in Oilseeds

S.No	Variety	Type of stress	Region of cultivation
1	**Groundnut** TMVGn 13	Drought	Thiruchirapalli, Thanjavur, Thiruvarur and Nagapattinam
2	ALR 3	Drought	Perambalur and Ariyalur
3	VRIGn 6	Drought	Thiruvallur, Cuddalore and Vellore
4	TMV 8, TMV 9 and TMV 10	Drought	Thiruvallur, Cuddalore, Vellore,Salem, Dharmapuri and Krishnagiri

5	M-13	Salinity	Thiruvallur, Cuddalore and Vellore
6	**Sesame** CO 1	Drought	Coimbatore,Thiruppur, Erode, Dindigul
7	TMV 3 and TMV 7	Drought	Madurai, Virudhunagar, Pudukkottai
8	VRI(SV) 2	Drought	Thiruvannamalai, Villupuram and Thiruvallur
9	SVPR 1	Drought	Ramanathapuram, Sivagangai, Thirunelveli, Thoothukudi
10	Castor TMV 5&6	Drought	All districts of Tamilnadu
11	**Sunflower** COSFV 5	Drought & Salinity	Coimbatore, Erode, Salem, Namakkal, Tirunelveli, Dindigul, Dharmapuri, Tiruchirapalli, Perambalur, Karur
12	TNAUSUF 7 (CO 4)		
13	**Coconut** VPM3	Drought	All districts of Tamilnadu
14	ALR (CN) 1		

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