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Effect of water stress and its management in vegetable crops: A review article

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Abstract

Climate change is the one of the major problem for low production of most of the vegetable crops worldwide that reducing average yield for most of the vegetable crops. Hostile environmental conditions such as drought, water logging, high saline levels, extreme temperatures, nutrients and other factors pose serious problems in production of vegetables. Among this water stress adversely affect on functioning of stomata, germination, growth reduction, premature senescence and reduce productivity. Water stress may be of two types *i.e.* drought and water logging. Mitigation of water stress is very important to reduce the yield loss. The water stress can be mitigating by mulching, use of Plant Growth Regulators, antitranspirants, hydrogel, grafting techniques and use of resistant varieties.

Keywords: Water stress, vegetable production, mitigation

Introduction

Vegetables are the important source of nutrition in Indian Agriculture after cereals and pulses. India secured second rank in vegetable production, next to China by covering an area of 10.1 million ha with the production of 185 million tonnes and productivity of 18.31 tonnes per ha (Anonymous, 2018) ^[1]. Vegetable plays an important role in human nutrition, called as protective food and this is particularly because of their consumption can defend against several diseases and considered as rich source of minerals, vitamins and fiber with high calorific values.

Abiotic stress constitutes one of the most significant limitations to vegetable production in the world today. Environmental conditions such as drought, high saline levels, extreme temperatures, poor soils and others pose serious problems.

Water stress is considered to be a moderate loss of water, which leads to stomatal closure and limitation of gas exchange. Water stress is characterized by reduction of water content, turgor, total water potential, wilting and decrease in cell growth & enlargement. In addition, abscisic acid (ABA), a plant stress hormone, induces the closure of leaf stomata (microscopic pores involved in gas exchange), thereby reducing water loss through transpiration. In vegetable crops, management of water stress can bring the production and productivity up to the mark. Management of water stress can be done by application of mulching, use of Plant Growth Regulators, antitranspirants, hydrogel and grafting techniques.

What is water stress?

Water stress can be defined as the absence of adequate soil moisture necessary for a plant to grow normally and complete its life cycle.

Type of water stress

Drought stress

It is the situation when there is not enough water to meet all demands, such as those required by an ecosystem to function

Flooding stress

Plant can't absorb the water due to the salinity, osmotic stress, water logging condition.

Factors responsible for water stress

Water stress is one of the most adverse factors of plant growth and productivity and considered a severe threat for sustainable crop production in the conditions on changing climate.

1. Erratic Rainfall
2. Poor Soil Water Storage
3. Less Capillary water in soil
4. Soil type
5. Irrigation channel
6. Saline water irrigation
7. Poor draining system
8. Water- logging
9. Plant architecture (Transpiration & Water uptake rate)
10. Global warming
11. Deforestation

Effect of Water Stress in Plant**Functioning of stomata**

Stomata lose their function and may die, because wilting after certain limit denature the starch in the guard cell and also in the mesophyll cells.

Growth

Affect Germination, Growth reduction, premature senescence and Reduction productivity.

Carbohydrate metabolism in green leaves: The very first effect of drought on carbohydrate metabolism is that starch disappears from wilted leaves following decrease in soil moisture and sugar accumulates, simultaneously. A low degree of drying stimulates activities of amylase and phosphorylase. The decomposition of carbohydrate beings in leaves where major influence of drought can be observed.

Biochemical effect

Water shortage in cell profoundly alters the chemical composition of plant, Starch converted into sugar, *i.e.* an increase in hexose sugar content.

Physiological adaptation to moisture stress**Water uptake is improved**

- Extensive root system with large active surface area
- Root/Shoot ratio shifted in favour of the roots

Water loss is reduced

- Transpiration reduced
- Thick cuticle
- Epicuticular waxes
- White hairs on leaves
- Leaf senescence
- Leaf shedding

Biochemical responses**Proline**

Proline can act as a signaling molecule to modulate mitochondrial functions and trigger specific gene expression, which can be essential for plant recovery from stress and Stabilizing sub-cellular structures, scavenging free radicals, maintain membrane integrity and reduces oxidation of lipid membranes under stress conditions

Antioxidant

Scavenging free radicals regulate number of metabolic process in plants exposed to drought stress and improve drought tolerance by enhancing the antioxidant mechanism

Polyamines

Polyamines are involved in flower induction, pollination, seed set and stress tolerance mechanism

Late Embryogenesis Abundant Protein

LEA proteins were initially discovered accumulating late in embryogenesis of cotton seeds and protect the plant against water stress; cold stress and high salinity also prevent protein aggregation due to water stress. They are highly hydrophilic and unstructured Associated with drought tolerance. LEA proteins are protective of mitochondrial membranes against dehydration damage.

Table 1: Effect of drought on growth and development on different vegetables

Vegetable	Critical Stage	Impact of water deficit
Tomato	Flowering and fruit enlargement	Flower shedding, BER, reduced fruit size
Eggplant	Flowering and fruit development	Less yield, poor color development
Chilli and capsicum	Flowering and fruit set	Shedding of flower and fruits
Cabbage and cauliflower	Head/curd formation, enlargement	Tip burning, splitting of head and riceyness in cauliflower
Root crops	Root enlargement	Distorted, rough and poor roots, splitting, Forking
Cucumber	Flowering and fruit development	Bitterness and deformity in fruits
Okra	Flowering and pod development	Loss of yield, fiber development
Melons	Flowering and fruit development	Poor fruit quality due to less TSS
Lettuce	Throughout development	Toughness in leaves, tip burning
Pea	Flowering and pod filling	Less root nodulation, poor grain filling
Potato	Tuberization and enlargement	Poor tuber growth and yield, splitting
Leafy vegetables	Throughout development	Toughness in leaves, poor foliage

Management of drought stress**1. Mulching**

The technique of covering the soil with natural crop residues or plastic films for soil and water conservation is called mulching. Mulching can be practiced in vegetable crops using crop residues and other organic material available in the farm.

2. Use of Plant Growth Regulators

Enhancing plant tolerant through foliar application of EPGR both natural and synthetic, has verified for enhancement

growth against a variety of abiotic stresses include drought, under drought stress, EPGR treatments increase water potential inside cell and improved chlorophyll content. Salicylic acid, gibberellin, Brassinosteroid, jasmonic acid, ethylene, auxins and cytokinins are responsible for drought tolerance in plants. CCC/ CC/ MC and Paclobutrazol Tolerance to water stress in many plant species. Abscisic acid (ABA) responsible for stomata regulation, root development, and initiation of ABA-dependent pathway.

3. Antitranspirants

Antitranspirants generally reduce photosynthesis. Therefore, their use is limited to save the crop from death under severe moisture stress.

Stomata closing: Most of the transpiration occur through the stomata on the leaf surface. Phenyl Mercuric Acetate (PMA) and Atrazine inducing stomatal closing. *i.e.* 2, 4 - D, Phosphon-D.

Film forming type

Plastic and waxy material which form a thin film on the leaf surface and result into physical barrier. Example: Mobileaf, Folicot, Waxol

Reflectance type

They are white materials which form a coating on the leaves and increase the leaf reflectance. Example: Kaoline, China Clay, Calcium bicarbonate, Lime water.

Growth retardant

These chemicals reduce shoot growth and increase root growth and thus enable the plants to resist drought. They may also induce stomatal closure. Cycocel is useful for improving water status of the plant.

4. Hydrogel

Hydrogel is prepared by grafting and cross-linking of water-absorbent polymers (polyacrylamide) onto a cellulose derivative backbone polymer chain (carboxymethyl cellulose). Hydrogel can be used effectively as it provides water to the growing plants on needed.

Application of hydrogel

Field condition

Prepare an admixture of hydrogel and fine dry soil in 1: 10 ratio and apply along with the seeds/fertilizers or in the opened furrows before sowing.

Nursery bed for transplant

Apply 2 g/m² of hydrogel uniformly in the top 2 inches of the nursery bed. In pot culture, mix 3–5 g/kg of hydrogel in soil before planting.

While transplanting

Thoroughly mix 2 g of hydrogel per litre of water to prepare a free-flowing solution; allow it to settle for half an hour. Dip the roots of the plant in the solution and then transplant in the field.

Pusa Hydrogel has been licensed to six companies for commercialization. It has become one of the key technologies of IARI having potentiality to become a leading component in second green revolution.

5. Grafting technique

In plant, water deficient condition is first recognized by roots.

But in grafted plant due to higher activity of H⁺-ATPase enzyme, it promotes large and deep root system to acquire water from the soil. (Sze *et al.*, 1999) [9].

Different methods of grafting

Tongue approach grafting (Melon and Cucumber), Hole insertion, Splice, Side and Cut grafting (Water melon), Cleft and tube grafting (Tomato, Brinjal and Capsicum), Apical wedge grafting (Capsicum) and Micro Grafting (Tomato)

Table 2: Potential rootstocks with special features of resistance against drought

Crop	Species	References
Tomato	<i>Solanum pennelli</i>	Bolger <i>et al.</i> (2014) [4]
	<i>S. chilense</i>	Zamir <i>et al.</i> (1994) [10]
Brinjal	<i>Solanum elaeagnifolium</i> <i>Solanum macrocarpum</i>	Christodoulakis <i>et al.</i> (2009) [5]

6. Use of resistant varieties

Table 3: Varieties developed through breeding method for drought resistance

Crop	Drought tolerant varieties
Tomato	Arka Vikas, Arka Meghali, Kashi Aman
Chilli	Arka Lohit
Onion	Arka Kalyan
Cluster bean	Karan Guar-1

Basic methods of drought management

Drip irrigation

It minimizes water losses due to run-off and deep percolation and water savings of 50-80% are achieved when compared to most traditional surface irrigation methods.

Water harvesting

Water harvesting for dry land is a traditional water management technology to ease future water scarcity in many arid and semi arid regions of the world. Rainwater and flood water harvesting have the potential to increase the productivity of arable land.

Protected cultivation

Protected structures can play important role to minimize the impact of temperature fluctuation, over/under precipitation and fluctuating sun shine hour and its role to minimize the impact of climatic change effect. Seedling rising in pro-trays and crop production inside agro-shade net also gaining popularity among the farmers.

Effect of water logging stress

1. Gas diffusion limitation (Metabolic toxins (soil or roots), reduced respiration (Energy deficiency), Reduced root Conductivity to water
2. Mineral nutrient deficiency

Table 4: Water stress management

Drought stress management		
Treatment	Result	References
Black plastic mulch	Increases yield parameters in chilli cv. Local	Ashrafuzzaman <i>et al.</i> (2011) [2]
Foliar spray of NAA 40 ppm at flower bud initiation	Maximize yield in chilli cv. Kashi Anmol	Patel <i>et al.</i> (2016) [7]
Foliar application of 0.5 mM SA at 30 DAP	Increases yield and quality of garlic cv. Pinkish Local	Bideshki and Arvin (2010) [3]
Foliar spraying of cycocel (5 mM)	High RWC (%) in growth stage in brinjal cv. CO 2	Prakash and Ramachandra (2001) [8]

Water logging stress management		
Treatment	Result	References
Grafting-SR pink & purple on <i>solanum torvum</i>	Higher fruit set and yield	Kumar <i>et al.</i> (2016) [6]

Conclusion

From the above discussion it can be concluded that water stress condition can be managed by use of mulching, PGRs, antitranspirants, hydrogel, proper irrigation method, use of protected structure, grafting on resistant rootstock and cultivation of resistant varieties for water stress condition to maximize vegetable production.

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