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Growing of vegetables under water deficiency and water logging

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Abstract
Drought and waterlogging are the most severe global problems for vegetables. When water is present in excess amount than its optimum requirement it refers to water logging. Drought stress occurs when the accessible water in the soil is concentrated and atmospheric circumstances cause permanent loss of water by evaporation or transpiration. In the water-logged soils, water gets filled in the pores of the soil, so the oxygen concentration decreases in soil. O deficiency decrease growth and survival of plants growing in it. The flooding 2 frequently induces stomatal closing mostly in C3 vegetable plants. Drought results in leaf dehydration; therefore, wilting of leaves occurs due to the limited water flow from the roots to the shoots. Waterlogging and drought affect a number of biological and chemical processes, which can impact crop growth in both the short and long term, in plants and soils. Germinating seeds are very sensitive to water logging and drought as their level of metabolism is high. Plants growing under stress conditions also demonstrate the formation of adventitious roots and formation of aerenchyma. Aim of this review paper is exhibit the vegetable plants responses to the water Logging and Water deficiencies.

Keywords: Waterlogging, vegetables, water deficiency

Introduction
In tropical and subtropical regions, excessive rainfall is the major constraint for vegetable crops. Elevated levels of water in soil create hypoxic conditions (decrease in the level of oxygen) within a short period of time. As a result, plant roots suffer from anoxia, complete absence of oxygen (Gambrell and Patrick, 1978) [14]. However, plants tolerant to waterlogging (flooding) stress exhibit certain adaptations, for example, formation of aerenchyma and adventitious roots. Furthermore, the formation of adventitious roots is due to the interaction of plant hormones, auxin and ethylene (McNamara and Mitchell, 1989) [19]. Oxygen deficiency inhibits the root respiration of plants which results in substantial reduction in energy status of root cells. Since oxygen is a terminal electron acceptor in aerobic respiration, in its absence, Kreb's cycle and electron-transport system are blocked. Therefore, plants under waterlogged conditions use alternate pathway for energy extraction. This alternate pathway uses fermentative metabolism to produce Adenosine triphosphate (ATP), thereby, resulting in enhanced accumulation of ethanol.

Moreover, the activity of alcohol dehydrogenase (ADH) is also increased (Davies, 1980; Vartapetian, 1991) [9, 25]. In fermentation, plants could get only two ATP per glucose molecule, whereas, 36 ATP molecules are produced per glucose molecule in aerobic respiration. Flood-tolerant plants are able to maintain their energy status using fermentation. In addition, the maintenance of cytosolic pH is of prime importance. In waterlogged plants, initial decline in cytosolic pH has been observed and this decline is attributed to the production of lactic acid during fermentation. This initial decrease in pH helps the plant to switch from lactate to ethanol fermentation by activation of alcohol dehydrogenase and inhibition of lactate dehydrogenase (Chang *et al*., 2000) [8]. As under hypoxic or anoxic conditions oxygen is lacking, therefore, alternative electron acceptor is required. It has also been suggested that nitrate reduction is an alternate respiratory pathway and is important for the maintenance and energy homeostasis of the cell in the oxygen deficient environment (Igamberdiev and Hill, 2004) [16].

One of the first plant responses to waterlogging is the reduction in stomata conductance (Folzer *et al*., 2006) [12]. Plants exposed to flooding stress exhibit increased stomata resistance as well as, limited water uptake leading to internal water deficit (Parent *et al*., 2008) [20]. In addition, low levels of O_2 may decrease hydraulic conductivity due to hampered root permeability (Else *et al*., 2001). Oxygen deficiency generally leads to the substantial decline in net photosynthetic rate. This decrease in transpiration and photosynthesis is attributed to stomata closure. However, other factors such as reduced chlorophyll contents, leaf senescence and reduced leaf area are also held responsible for decreased rates of photosynthesis (Malik *et al*., 2001) [18]. When pea plants were subjected to flooding conditions, a prompt closure of stomata was recorded (Zang and Zang, 1994) [30]. This stomata closure of pea plants was attributed to the abscisic acid (ABA) transport from older to younger leaves or denovo synthesis of this hormone. Furthermore, prolonged exposure of plants to flooding conditions could result in root injuries which in turn restrict photosynthetic capacity by inducing certain alterations in biochemical reactions of photosynthesis. Likewise, decrease in the maximum quantum yield of PS II photochemistry (Fv/Fm) was also recorded in flied beans when subjected to varying days of waterlogging stress, PSII photochemistry was also impaired due to waterlogging in *Medicago sativa*. The decrease in Fv/Fm indicated the sensitivity of photosynthetic apparatus to abiotic stress and also inability of the plants to regenerate rubisco under stress environment.

Oxidative damage induced by reactive oxygen species (ROS)

Despite the fact that oxygen is important for life on earth, its reduction by any means could result in the production of ROS perturbing several cellular metabolic processes of plants (Ashraf, 2009) [2]. Lethal reactive oxygen species include superoxide (O_2), hydrogen peroxide (H_2O_2) and the hydroxyl radical (OH). Singlet oxygen generated due to the reaction of oxygen with excited chlorophyll, is also considered as potential ROS (Ashraf and Akram, 2009) [2]. These ROS are extremely reactive in nature and induce damage to a number of cellular molecules and metabolites such as proteins, lipids, pigments, DNA etc (Ashraf, 2009) [2]. ROS are also produced in plants under normal conditions or non-stresses conditions but their concentration is very low. However, when plants are facing some environmental stress like waterlogging stress, the concentration of ROS is elevated to a level that is damaging for several cellular metabolic reactions of plants such as photosynthesis, efficiency of PS II (Ashraf, 2009) [2]. For example, elevated cellular levels of hydrogen peroxide result in inhibition of calvin cycle (Ashraf and Akram, 2009) [2]. ROS are free radicals possessing one or more unpaired electrons. This is not a stable configuration; therefore, the radicals react with other cellular molecules to produce more free radicals (Foyer and Halliwell, 1976) [13]. Generation of reactive oxygen species occurs via different mechanisms, for example, when molecules of aerobic system come in contact with the ionizing radiations, this interaction results in the production of ROS. It is now a well-established fact that electrons flowing through electron transport chain may leak from their proper rout and in the absence of any electron acceptor, these electrons react with oxygen to produce reactive oxygen species (Ashraf, 2009) [2]. Different cellular organelles such as mitochondria, chloroplasts and peroxisomes are considered as the sites for production of reactive oxygen species (Sairam and Srivastva, 2002) [22].

Water logging-induced alterations in physiological mechanisms

One of the first plant responses to waterlogging is the reduction in stomata conductance (Folzer *et al*., 2006) [12]. Plants exposed to flooding stress exhibit increased stomata resistance as well as, limited water uptake leading to internal water deficit (Parent *et al*., 2008) [20]. In addition, low levels of O_2 may decrease hydraulic conductivity due to hampered root permeability. Oxygen deficiency generally leads to the substantial decline in net photosynthetic rate. This decrease in transpiration and photosynthesis is attributed to stomata closure. However, other factors such as reduced chlorophyll contents, leaf senescence and reduced leaf area are also held responsible for decreased rates of photosynthesis (Malik *et al*., 2001) [18]. When pea plants were subjected to flooding conditions, a prompt closure of stomata was recorded (Zang and Zang, 1994) [30]. This stomata closure of pea plants was attributed to the abscisic acid (ABA) transport from older to younger leaves or denovo synthesis of this hormone. Furthermore, prolonged exposure of plants to flooding conditions could result in root injuries which in turn restrict photosynthetic capacity by inducing certain alterations in biochemical reactions of photosynthesis. These biochemical alterations include restricted activity of waterlogging stress, a prominent decrease in maximum quantum efficiency (Fv/Fm). PSII photochemistry was also impaired due to waterlogging in *Medicago sativa*.

Fig 1: Showing cracks and spots in tomato fruit due to water logging.

Effect of waterlogging on nutrient composition

Oxygen deficiency in the root zone causes a marked decline in the selectivity of K+ /Na+ uptake .It has also been reported in the literature that hypoxic conditions cause decrease in the permeability of root membranes to Na+ (Barrett-Lennard *et al*., 1999) [6]. Boem *et al*. (1996) [7] reported a marked decline in the uptake of N, P, K and Ca in canola when exposed to short period of waterlogging stress. Likewise, reduced endogenous levels of N, P and K have been reported in maize (Atwell and Steer, 1990) [5]. In contrast, the endogenous levels of calcium remained unaffected in wheat under waterlogged conditions. However, decrease in calcium contents along with other nutrients (N, P, K and Mg) were also recorded in different organs of wheat under waterlogged conditions (Sharma and Swarup, 1989) [23]. These researchers were of the view that genotypes that possess the ability to avoid waterlogging-induced nutrient deficiency, particularly Zn and P deficiency should be selected. It is evident from the literature that adverse effects of waterlogging are not due to the toxic levels of Na and Fe but reduced concentrations of N, P, K, Ca and Mg are the major contributors (Sharma and Swarup, 1989) [23].

Genetic variation for waterlogging toleransce

Plants under waterlogged conditions exhibit marked up and/or down-regulation of a number of genes. By investigating the induced expression of these genes in low oxygen environment, it is possible to identify certain gene products. Then these potential genes involved in conferring waterlogging tolerance can be isolated and introduced into the transgenic plants in order to identify their possible contribution in stress tolerance. Early studies performed by isotopic labeling of maize roots with 35S-methionine clearly indicated the synthesis of anaerobic polypeptides when plants were subjected to low oxygen environment (Sachs *et al*., 1980) [21]. The anaerobic polypeptides include the enzymes involved in fermentation, that is, pyruvate decarboxylate, alcohol dehydrogenase and lactate dehydrogenase. Moreover, there exists a marked variation in genetic resources of potential crops for flooding tolerance. For example, it has been widely reported in the literature that genetic differences exist in wheat for waterlogging tolerance (Grander and Flood, 1993; Ding and Musgrave, 1995) [15, 10]. There also exists a significant genetic diversity among 14 wheat varieties when exposed to flooding stress under glasshouse conditions. Similar, genetic variation has also been reported in cucumber (Yeboah *et al*., 2008) [27].

Shotgun approaches to induce waterlogging tolerance

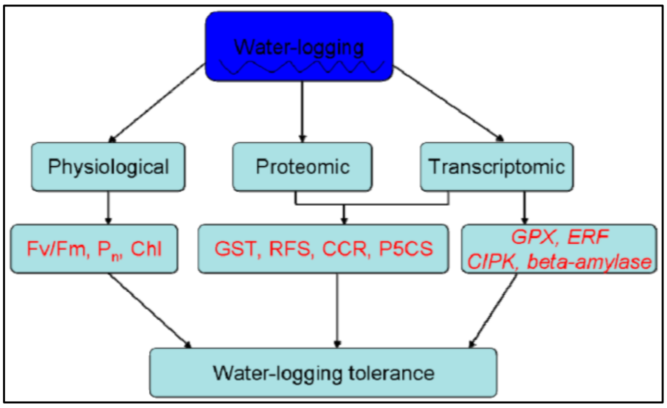

Fig 2: A schematic representation for waterlogging stress responses in alfalfa plants.

Scientists from different geographical regions of the world are actively involved in making the plants tolerant to flooding stress by the use of exogenous application of nutrient and plant hormones. Recently, Ashraf and Rehman (1999) [4] reported that application of nitrate in soil proved useful in mitigating the harmful effects of waterlogging on different physiological attributes of maize. Likewise, Yiu *et al*. (2009) [28] found that exogenous application of spermidine and spermine provoked several biochemical and physiological adaptations in onion when exposed to flooding stress. Therefore, the use of these organic and inorganic compounds offers an excellent platform for inducing tolerance to flooding stress.

Conclusion

It can be inferred from the aforesaid discussion that waterlogging is one of the major constraints for sustainable agriculture. Its effects are evident on the entire plant as well as, cellular levels. There is the need to screen available germplasm for waterlogging tolerance and use the genes responsible for inducing tolerance in other potential crops so as to make them resistant as well. Waterlogging causes deficiency of several essential nutrients. Therefore, exogenous application of these nutrient or other plant hormones could be used so as to alleviate the adverse effects of waterlogging.

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