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Management practices for vegetable production against climate change

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Climate change is the primary cause of low production of most of the vegetables worldwide; reducing average yields for most of the major vegetables. Moreover, increasing temperatures, reduced irrigation-water availability, flooding, and salinity will be the major limiting factors in sustaining and increasing vegetable productivity. This article may contribute in improving the adaptation strategies of vegetable production to climate change for a sustainable horticulture due to an effective risk management by meeting the problems of possible crop management practices like mulching with crop residues and plastic mulches help in conserving soil moisture. Excessive soil moisture due to heavy rain becomes major problem that can be overcome by growing crops on raised beds. Development of genotypes tolerant to high temperature, moisture stress, salinity and climate proofing through conventional, non-conventional, breeding techniques, genomics and biotechnology etc. are essentially required to meet these challenges.

Climate change may be a change in the mean of the various climatic parameters such as temperature, precipitation, relative humidity and atmospheric gases composition etc. and in properties over a longer period and a larger geographical area. It can also be referred as any change in climate over time, whether due to natural variability or because of human activity. The vulnerability of any system to climate change is the degree to which these systems are susceptible and unable to survive with the adverse impacts of climate change. They also explained the concept of risk as which combines the magnitude of the impact with the probability of its occurrence, captures uncertainty in the underlying processes of climate change, exposure, impacts and adaptation. The changing patterns of climatic parameters like rise in atmospheric temperature, changes in precipitation patterns, excess UV radiation and higher incidence of extreme weather events like droughts and floods are emerging major threats for vegetable production in the tropical zone (Kumar *et al.*, 2011). Vegetable crops are very sensitive to climatic vagaries and sudden rise in temperature as well as irregular precipitation at any phase of crop growth can affect the normal growth, flowering, pollination, fruit development and subsequently decrease the crop yield. Moreover, climate change is fostering the spread of pathogens and the evolution of new strains of insect pests and fungal, bacterial and virus diseases. Challenges ahead are to have sustainability and competitiveness, to achieve the targeted production to meet the growing demands in the environment of declining land, water and threat of climate change, which needs climate-smart vegetable interventions, which are highly location-specific and knowledge intensive for improving production in the challenged environment.

Impact of climate change on vegetable production: Vegetables crops, like other agricultural crops, are sensitive to climate variability. Vegetables are generally sensitive to environmental extremes, and thus high temperature are the major causes of low yields and will be further magnified by climate change. Some of the important environmental stresses that affect vegetable crop production will be mention below (Malhotra and Srivastava, 2015).

Temperature: Fluctuations in daily mean maximum and minimum temperature is the primary affect of climate change that adversely affects vegetable production, as many plant physiological, bio-chemical and metabolic

Table 1: Increase in atmospheric concentration of green house gases since pre- industrial times (WMO, 2013; Permission obtained)

Green house gas	Conc. in 2010	Increase since pre- industrial time
Carbon dioxide	389 ppm	39 %
Methane	1808 ppb	158 %
Nitrous oxide	323.2 ppb	20 %

activities are temperature dependent. The occurrence of high temperature influences the vegetable production in tropical and arid areas. High temperature causes a significant alteration in morphological, physiological, biochemical and molecular response of the plant and in turn affects the plant growth, development and yield.

Drought: Water availability is expected to be highly sensitive to climate change and severe water stress conditions will affect crop productivity, particularly that of vegetables. Drought is a major problem in arid and semi-arid regions, which is the primary cause of crop loss worldwide, reducing average yields for most of the crop plants by more than 50 per cent. Drought stress because of insufficient rainfall or deficient soil moisture might induce various biochemicals, physiological and genetic responses in plants, which severely restricted crop growth. Prevalence of drought conditions adversely affects the germination of seeds in vegetable crops like onion and okra and sprouting of tubers in potato. The drought condition induces flower abscission in tomato. More than 50 per cent yield reduction was reported in tomato because of water stress during reproductive stage. It has been suggested that water stress at flowering stage reduces photosynthesis and the amount of photosynthetic assimilates allocated to floral organs and might thereby increase the rate of abscission. Drought stress causes an increase of solute concentration in the environment (soil), leading to an osmotic flow of water out of plant cells.

Salinity: Salinity is a serious problem that reduces growth and productivity of vegetable crops in many salt-affected areas. Excessive soil salinity reduces productivity of many agricultural crops, including most vegetables, which are particularly sensitive throughout the ontogeny of the plant. Physiologically, salinity imposes an initial water deficit that results from the relatively high solute concentrations in the soil, causes ion-specific stresses resulting from altered K+ /Na+ ratios, and leads to a buildup in Na+ and Cl- concentrations that are detrimental to plants. Salt stress causes loss of turgor, reduction in growth, wilting, leaf abscission, decreased photosynthesis and respiration, loss of cellular integrity, tissue necrosis and finally death of the plant.

Flooding: Flooding is another important abiotic stress and cause serious problems for the growth and yield of vegetable crops, which are generally considered flood-susceptible crops. Most vegetables are highly sensitive to flooding and genetic variation with respect to this character is limited, particularly in tomato. In general, damage to vegetables by flooding is due to the reduction of oxygen in the root zone, which inhibits aerobic processes. Flooded tomato plants accumulate endogenous ethylene that causes damage to the plants. The rapid development of epinastic growth of leaves is a characteristic response of tomatoes to waterlogged conditions and the role of ethylene accumulation has been implicated (Kuo *et al.*, 2014). The severity of flooding symptoms increases with rising temperatures; rapid wilting and death of tomato plants is usually observed following a short period of flooding at high temperatures. Onion is also sensitive to flooding during bulb development with yield loss upto 30-40 per cent. These stresses are the primary cause of yield losses worldwide by more than 50 per cent plant and the response of plants to environmental stresses depends on the developmental stage and the length and severity of the stresses.

Management practices for adapting climate change: Cultural management practices: The emphasis should be on use of recommended production systems for improved water-use efficiency and to adapt to the hot and dry conditions. According to Welbaum (2015) strategies like changing sowing or planting dates in order to combat the likely increase in temperature and water stress periods during the crop-growing season should be adopted. Modifying fertilizer application to enhance nutrient availability and use of soil amendments to improve soil fertility and enhance nutrient uptake. Providing irrigation during critical stages of the crop growth and conservation of soil moisture reserves are the most important interventions. The crop management practices like mulching with crop residues and plastic mulches help in conserving soil moisture. In some instances excessive soil moisture due to heavy rain becomes a major problem and it could be overcome by growing crops on raised beds.

Improved stress tolerance through grafting: Grafting vegetables originated in East Asia during the 20th century with the objective of reducing the affects of soilborne diseases like fusarium wilt, which affects the production of vegetables such as tomato, eggplant and cucurbits. Now-a-days, grafting is considered as a common practice in vegetable production in Asian countries such as Japan, Korea and some European countries which is an efficient rapid alternative tool to the relatively slow breeding methodology aimed at enhancing environmental-stress tolerance of horticultural crops in general and vegetables in particular. Grafting is one of the promising tools for modifying the root system of the plant for enhancing its tolerance to various abiotic stresses. In vegetable crops, grafted plants are now being used to improve resistance

against abiotic stresses like low and high temperatures, drought, salinity and flooding if appropriate tolerant rootstocks are used. Because of these beneficial effects of grafting, the cultivation of grafted plants in crops like tomato, eggplant and pepper and cucurbits (melon, cucumber, watermelon and pumpkin) has increased in recent years.

Developing climate resilient vegetables: Improved, adapted vegetable germplasm is the most cost-effective option for farmers to meet the challenges of a changing climate. However, most modern cultivars represent a limited sampling of available genetic variability including tolerance to environmental stresses. Breeding new varieties, particularly for intensive, high input production systems in developed countries, under optimal growth conditions may have counter-selected for traits that would contribute to adaptation or tolerance to low input and less favorable environments. Superior varieties adapted to a wider range of climatic conditions could result from the discovery of novel genetic variation for tolerance to different biotic and abiotic stresses. Genotypes with improved attributes conditioned by superior combinations of alleles at multiple loci could be identified and advanced. Improved selection techniques are needed to identify these superior genotypes and associated traits, especially from wild, related species that grow in environments, which do not support the growth of their domesticated relatives that are cultivated varieties. Plants native to climates with marked seasonality are able to acclimatize more easily to variable environmental conditions and provide opportunities to identify genes or gene combinations that confer such resilience.

Biotechnology: Increasing crop productivity in unfavourable environments will require advanced technologies to complement traditional methods, which are often unable to prevent yield losses due to environmental stresses. Genes have been discovered and gene functions understood. This has opened the way to genetic manipulation of genes associated with tolerance to environmental stresses. These tools promise more rapid, and potentially spectacular, returns but require high levels of investment. Many activities using these genetic and molecular tools are in place, with some successes. Molecular marker analysis of stress tolerance in vegetables is limited but efforts are underway to identify QTLs underlying tolerance to stresses. QTLs for drought tolerance have been identified in tomato (Sung et al., 2003).

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