Agri Articles
(e-Magazine for Agricultural Articles)
Volume: 03, Issue: 04 (JULY-AUGUST, 2023)
Available online at http://www.agriarticles.com
©Agri Articles, ISSN: 2582-9882

Impact of Climate Change on Vegetable Production

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India with diverse soil and climate comprising several agro-ecological regions provides ample opportunity to grow a variety of horticultural crops which form a significant part of total agricultural produce in the country comprising of fruits, vegetables, root and tuber crops, flowers and other ornamentals, medicinal and aromatic plants, spices, condiments, plantation crops and mushrooms. It is estimated that all the horticulture crops put together cover nearly 11.6 million hectares area with an annual production of 91 million tonnes. According to the Intergovernmental Panel on Climate Change (IPCC), the combustion of fossil energy sources and the associated emissions of greenhouse gases (GHG), eg. CO_2, N_2O, CH_4, cause an accumulation of the latter in the atmosphere (IPCC, 2013).

Effect of temperature on flowering and product quality

Temperature steers chemical and differentiation processes within the plant thereby determining growth speed, development rate, and the growth period of horticultural crops. White asparagus, for instance, is traditionally cultivated in dams due to the earlier warming in spring, and hence earlier growth. Double-sided plastic mulch, where the white side has a delaying, and the black side has an advancing effect, are used to force earlier spear growth. The black side is often combined under plastic tunnels for an even earlier harvest.

In bush bean, flower expression is accelerated at temperatures between 25 - 30 °C, but only in day neutral cultivars *ie*. independent of photoperiod, which predominate in Germany. Siddiq and Goodwin (1980), showed in a glasshouse study that common bean (Phaseolus vulgaris L.) grown at temperatures above 27/22 °C (day/night) during seed development, matured early and produced small seeds compared to beans grown at 21/16 °C. Similarly, high temperatures accelerated development of pea plants, thereby reducing their crop duration, biomass production and yield, eg. at 24 °C compared to 16 °C mean in CE chambers.

Summer Heat Waves reduce fruit-set and product quality

The probability of heat waves has doubled in Europe over the last decades, with likely further increases in their future frequency and duration (IPCC, 2013). Heat spells are characterized by temperatures exceeding 30 °C and intense solar radiation at an unfavorable vapor pressure deficit (VPD). In horticulture, such conditions can have serious implications on plant growth, health, yield, and product quality, due to damages in cellular membranes, proteins, nucleic acids, and the adverse effects on pigment synthesis and degradation

Flowering and fruit set

Fruit set, a prerequisite for yield in fruiting vegetables, relies on pollen release and germination, which can both be impaired by exposure to heat. In heat-sensitive common bean cultivars (Phaseolus vulgaris L.), temperatures of 32/27 °C (day/night), caused abnormal pollen and anther development, poor ovule fertilisation and increased flower abscission with a resulting low yield. Impeded pollen production and release, with a reduced fruit set, at 37/27 °C (day/night) in tomato. The same authors showed that high night temperatures (37/27 °C compared to 37/22 °C Day/night) reduced fruit set, but only in sensitive varieties, with increased occurrence of flower abortion, fruit abscission, parthenocarpic and undeveloped fruit in all cultivars

Salinity effect on vegetables

In hot and dry environments, high evapotranspiration results in substantial water loss, thus leaving salt around the plant roots which interferes with the plant's ability to uptake water. 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.

Plant sensitivity to salt stress is reflected in loss of turgor, growth reduction, wilting, leaf curling and epinasty, leaf abscission, decreased photosynthesis, respiratory changes, loss of cellular integrity, tissue necrosis, and potentially death of the plant. Salinity also affects agriculture in coastal regions which are impacted by low-quality and high saline irrigation water due to contamination of the groundwater and intrusion of saline water due to natural or man-made events.

The Need for Adaptation to Climate Change

Potential impacts of climate change on agricultural production will depend not only on climate per se, but also on the internal dynamics of agricultural systems, including their ability to adapt to the changes. Success in mitigating climate change depends on how well agricultural crops and systems adapt to the changes and concomitant environmental stresses of those changes on the current systems. Farmers in developing countries of the tropics need tools to adapt and mitigate the adverse effects of climate change on agricultural productivity, and particularly on vegetable production, quality and yield.

Current, and new, technologies being developed through plant stress physiology research can potentially contribute to mitigate threats from climate change on vegetable production. However, farmers in developing countries are usually small-holders, have fewer options and must rely heavily on resources available in their farms or within their communities. Thus, technologies that are simple, affordable, and accessible must be used to increase the resilience of farms in less developed countries.

Flooding

Vegetable production occurs in both dry and wet seasons in the tropics. However, production is often limited during the rainy season due to excessive moisture brought about by heavy rain. 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.

Low oxygen levels stimulate an increased production of an ethylene precursor, 1-aminocyclopropane-1-carboxylic acid (ACC), in the roots. The rapid development of epinastic growth of leaves is a characteristic response of tomatoes to water-logged conditions and the role of ethylene accumulation has been implicated. 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.

Cultural practices that conserve water and protect crops

Various crop management practices such as mulching and the use of shelters and raised beds help to conserve soil moisture, prevent soil degradation, and protect vegetables from heavy rains, high temperatures, and flooding. The use of organic and inorganic mulches is common in high-value vegetable production systems. These protective coverings help reduce evaporation, moderate soil temperature, reduce soil runoff and erosion, protect fruits from direct contact with soil and minimize weed growth. In addition, the use of organic materials as mulch can help enhance soil fertility, structure and other soil properties. Rice straw is abundant in rice-growing areas of the tropics and generally recommended for summer tomato production. The benefits of rice straw mulch on fruit yield of tomato have been demonstrated in Taiwan (AVRDC 1981).

Improved stress tolerance through grafting

Grafting vegetables originated in East Asia during the 20th century and is currently common practice in Japan, Korea and some European countries. Grafting, in this context, involves uniting of two living plant parts (rootstock and scion) to produce a single growing plant. It has been used primarily to control soil-borne diseases affecting the production of fruit vegetables such as tomato, eggplant, and cucurbits. However, it can provide tolerance to soil-related environmental stresses such as drought, salinity, low soil temperature and flooding if appropriate tolerant rootstocks are used.

Grafting of eggplants was started in the 1950s, followed by grafting of cucumbers and tomatoes in the 1960s and 1970s. It was found that melons grafted onto hybrid squash rootstocks were more salt tolerant than the non-grafted melons. However, tolerance to salt by rootstocks varies greatly among species, such that rootstocks from *Cucurbita* spp. are more tolerant of salt than rootstocks from *Lagenaria siceraria*. Grafted plants were also more able to tolerate low soil temperatures. *Solanum lycopersicum* x *S. habrochaites* rootstocks provide tolerance of low soil temperatures (10 C to 13 C) for their grafted tomato scions, while eggplants grafted onto *S. integrifolium* x *S. melongena* rootstocks grew better at lower temperatures (18 C to 21 C) than non-grafted plants.

Causes of climate change

- ✓ Deforestation
- ✓ Fossil fuel consumption
- ✓ Urbanisation
- ✓ Land reclamation
- ✓ Agricultural intensification
- ✓ Freshwater extraction
- ✓ Fisheries overexploita

Conclusion

- ✓ Climate change will lead to more periods of high temperature and periods of heavy rain. Unseasonal or extreme weather will have an increasing impact on crop production. There are already examples of what to expect.
- ✓ Modelling can help predict consequences and guide adaptation. Development of production system, improved varieties with improved water use efficiency. Screening and validation of the cloned genes in model crops such as tomato.
- ✓ Patenting elite genes and promoters In India, diverse climatic conditions, available across the country provide ample opportunity to grow almost all types of vegetable crops, thus making our country the second largest producer of vegetables.