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Effect of Climate Change on Vegetable Crops – A Review

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1. INTRODUCTION

Indian horticulture is the core sector of agriculture, representing a broad spectrum of crops and production of a wide range of horticulture crops – fruits, vegetables, nuts, ornamental, plantation, tuber, spices, medicinal and aromatic crops and mushrooms. These horticultural crops make a significant contribution to the Indian economy, in terms of rural employment generation and farmers income. Increase in demand for horticultural produce due to greater health awareness, rising income, export demands, and increasing population poses the challenge for further increasing the production and productivity of horticultural crops. The issue of climate change and climate variability has thrown up greater uncertainties and risks, further imposing constraints on horticultural production systems. The 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 innovations it adoption for improving production challenged environment.

The world’s population predicted to reach 9 billion by 2050; we collectively face a dual challenge: ensuring that everyone will have access to affordable, nutritious food without decimating the earth’s natural resources in the process. This is easier said than done. Our current food systems are dysfunctional both in its impact on people and the planet. Unless we change course, we will fail to meet this challenge. Today, millions do not have enough to eat and billions lack the right nutrients to be healthy. The United Nation’s food Organizations - the Food and Agriculture Organization (FAO), the World Food Programme (WFP)and the World Health Organization (WHO) have just published their annual report on global food insecurity which highlights that despite some evidence of progress 805 million people or 1 in 9 people, still suffer from hunger.

Poor diets stunt the growth of 162 million children every year, 97 per cent of them in the developing world, trapping communities in a cycle of poverty and ill-health. The consequences for those affected can be devastating. Malnourished children tend to start school later, have poorer levels of concentration and lower scores levels of concentration and lower scores in cognitive ability tests. Many carry these burdens through into later life.

2. CLIMATOLOGY

Climatology it is the study of climate, scientifically defined as weather conditions averaged over a period of time**.** Climate refers to the sum total of weather conditions and variations over a large area for a long period of time (more than thirty years). The world climate can be studied by organizing information and data on climate and synthesizing them in smaller units for easy understanding, description and analysis. Three broad approaches have been adopted for classifying climate. They are empirical, genetic and applied. Empirical classification is based on observed data, particularly on temperature and precipitation. Genetic classification attempts to organize climates according to their causes. Applied classification is for specific purpose.

3. VEGETABLES

India is the second largest producer of vegetables in the world (ranks next to China) and accounts for about 15% of the world’s production of vegetables. The current production level is over 90 MT and the total area under vegetable cultivation is around 6.2 million hectares which is about 3% of the total area under cultivation in the country.

4. INFLUENCE OF CLIMATIC CHANGES ON VEGETABLE CROPS

Environmental stress is the primary cause of crop losses worldwide, reducing average yields for most major crops by more than 50% (Bray *et al.* 2000). Climatic changes will influence the severity of environmental stress imposed on vegetable crops. The response of plants to environmental stresses depends on the plant developmental stage and the length and severity of the stress (Bray, 2002). Plants may respond similarly to avoid one or more stresses through morphological or biochemical mechanisms Capiati *et al*. (2006). Environmental interactions may make the stress response of plants more complex or influence the degree of impact of climate change. Lists of some abiotic stress vegetables and their varieties have been presented in Table-2 and 3 respectively. High temperatures can cause significant losses in tomato productivity due to reduced fruit set, and smaller and lower quality fruits. Pre-anthesis temperature stress is associated with developmental changes in the anthers, particularly irregularities in the epidermis and endothesium, lack of opening of the stromium, and poor pollen formation (Sato *et al*. 2002). Hazra *et al*. (2007) reported that symptoms causing fruit set failure at high temperatures in tomato s includes bud drop, abnormal flower development, poor pollen production, dehiscence, and viability, ovule abortion and poor viability, reduced carbohydrate availability, and other reproductive abnormalities. In pepper, high temperature exposure at the pre-anthesis stage did not affect pistil or stamen viability, but high post-pollination temperatures inhibited fruit set, suggesting that fertilization is sensitive to high temperature stress (Erickson and Markhart 2002). 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.

Most of the vegetable crops are highly sensitive to flooding and genetic variation with respect to this character is limited. Flooded crops especially in tomato plants accumulate endogenous ethylene that causes damage to the plants (Drew 1979). Under low oxygen levels stimulate an increased production of an ethylene precursor, 1-aminocyclopropane-1-carboxylic acid (ACC), in the roots. 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 (Kuo *et al*. 1982). During the last 40-50 years air pollution level increasing at an alarming rate in the developing countries and causing potential threat to the crop production. Sulphar dioxide, nitrogen oxide, hydrofluride, ozone and acid rain are the primary air pollutant. Ozone has adverse effect on vegetable production in terms of reducing growth, yield and quality. Risk of the air pollution is more when vegetable crops grown close to the densely populated areas. A recent study indicated that the ambient air pollution significantly decreased the yield upto more than 50 percent incase of *Brassica oleracia*, *Lactuca sativa* and *Raphanussativus*. Many vegetable crops namely tomato, water melon, potato, squash, soyabeans, cantaloupe, peas, carrot, beet, turnip, etc are more susceptible to air pollution damage. Yield of vegetable can be reduced by 5-15 percent when daily ozone concentrations reach to greater than 50 ppb (Raj Narayan 2009).

5. IMPACT OF CLIMATE CHANGE ON VEGETABLES CROPS:

Indian climate dominated by the monsoon, responsible for most of the region's precipitation, poses excess and limited water stress conditions. Vegetables being succulent are generally sensitive to environmental extremes and high temperature, limited and excess moisture stresses are the major causes of low yields. Under climate change scenarios the impact of these stresses would be compounded.

Table 1: Optimal soil temperatures lower and lower lethal thresholds for germination of some vegetable crops are as follows.

Crop	Lower lethal (^{o}C)	Lower threshold (^{o}C)	Optimal range (^{o}C)
Cabbage	0	4	7 to 35
Pea	-1	<4	4 to 24
Radish	-1	<4	7 to 35
Tomato	2	<10	15 to 29

In tomato, high temperatures can cause significant losses in productivity due to reduced fruit setting, smaller size and low quality fruits. Optimum daily mean temperature for fruit setting in tomato has been reported to be 21-24^{0}C. The pre-anthesis is more sensitive in tomato. Post pollination exposure to high temperature inhibits fruit setting in pepper, indicating sensitivity of fertilization process. In cucumber, sex expression is affected by temperature.

Low temperatures favours female flower production, which is desirable and high temperatures lead to production of more male flowers. The duration of onion gets shortened due to high temperature leading to reduced yields.

Cauliflower performs well in the temperature range of 15-25^{0}C with high humidity. Though some varieties have adapted to temperatures over 30^{0}, most varieties are sensitive to higher temperatures and delayed curd initiation is observed.

In onion temperature increase above 40^{0}C reduced the bulb size and increase of about 3.0^{0}C above 38^{0}C reduced yield by19%. Warmer temperatures shorten the duration of growth leading to lower crop yields

In potato, reduction in marketable grade tuber yield to the extent of 10-20% is observed due to high temperature and frost damage reduced tuber yield by 10-50%, depending upon intensity and stage of occurrence. Temperature increase beyond 20^{0}C during winter affects cultivation of seasonal button mushroom and increased incidence of disesases.

Occurrence of frost during January in Rajasthan affects cumin resulting in total crop failure.

Temperature rise from 20-22^{0}C will increase the incidence of pest and diseases in case of cymbidium orchid.

Any soil warming would be advantageous for cucurbits, which are generally direct seeded and have a high heat requirement.

The rise in temperature will influence survival and distribution of pest population; developing new equilibrium between alternate host crops and pests; hasten nutrient mineralization in soils; decrease fertilizer-use efficiency; and increase evapotranspiration with reduced water-use efficiency. The net effect of climate change on horticultural crops will depend on interaction effects of rise in temperature and CO_2 concentration in atmosphere, in general, CO_2 enrichment does not appear to compensate for the detrimental effects of higher temperature on yield. Most importantly, the quality of produce of the se horticultural corps is likely to be impacted severely.

Table 2: List of some abiotic stresses vegetable crops

Sl. No.	Tolerant	Crop
1	Drought tolerant	Chilli, melons, tomato, onion
2	Heat tolerant	Peas, tomato, beans, Capsicum
3	Salinity tolerant	melons, peas, onion
4	Flooding/ excess moisture tolerant	tomato, onion, chilli

Source: Rai and Yadav (2005)

Table 3: List of some variety and advanced line tolerant to abiotic stress.

Sl. No.	Tolerant	Crop	Variety	Advanced Line
1	Drought/rainfed	Tomato	ArkaVikas	RF- 4A
		Onion	ArkaKalyan	MST-42 and MST-46
		Chilli	ArkaLohit	IIHR Sel.-132
2	Photo insensitive	Dolichos	Arka Jay, Arka Vijay, arkaSambram, Arka Amogh, ArkaSoumya	IIHR-16-2
		Cow pea	Arkagarima, Arka Suman, ArkaSamrudhi	
3	High temperature	Capsicum		IIHR Sel.-3
		Frenchbean		IIHR-19-1
		Peas		IIHR-1 and IIHR-8
		Cauliflower		IIHR 316-1 and IIHR-371-1

Source: Hazra and Som (1999) and Rai and Yadav (2005)

6. EFFECT OF HIGH TEMPERATURE STRESS ON TOMATO

Continuous exposure of tomato 'Trust' to high temperatures(day/night temperatures of 32/26 °C) markedly reduced the number of pollen grains per flower and decreased viability. The effect of heat stress on pollen viability was associated with alterations in carbohydrate metabolism in various parts of the anther during its development. Under control, favorable temperature conditions (28/22 °C), starch accumulatedin the pollen grains, where it reached a maximum value 3 d before anthesis; it then diminished towards anthesis. During anther development, the concentration of total soluble sugars gradually increased in the anther walls and in the pollen grains(but not in the locular fluid), reaching a maximum at anthesis. Continuous exposure of the plants to high temperatures (32/26 °C) prevented the transient increase in starch concentration and led to decreases in the concentrations of soluble sugars in the anther walls and the pollen grains. In the locular fluid,however, a higher soluble sugar concentration was detected under the high-temperature regime throughout anther development. These results suggest that a major effect of heat stress on pollen development is a decrease in starch concentration 3 d before anthesis, which results in a decreased sugar concentration in the mature pollen grains. These events possibly contribute to the decreased pollen viability in tomato.

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