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Effect of Climate Change on Vegetable Production- A Review

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A B S T R A C T

Vegetables are one of the good sources of vitamins and minerals and play an important role in ensuring food and nutritional security. Vegetables are highly perishable and very sensitive to unpredictable climatic changes. Climate change has an adverse impact on productivity and quality besides aggravate the environmental stress on vegetable crops. Environmental stresses like increasing temperature, reduced irrigation water availability, flooding and salinity are thought to be the major limiting factors in enhancing vegetable productivity. Though the climate vagaries are beyond human control, its intensity and extreme impact of environmental stress on vegetable crops can be reduced to some extent and enhance the production as well, if the integrated approaches like cultural management practices including nutrient and tillage residue management, water management, mulching, improved pest management, and breeding approaches like development of genotypes tolerant to high temperature, salinity, moisture stress are resorted.

Introduction

Climate variability is one of the most significant factors influencing year to year crop production, even in high-yield and high-technology agricultural areas (Kang *et al.*, 2009). Climate change, which includes increase in temperature, changes in rainfall pattern, sea level rise, salt-water intrusion, generation of floods and droughts is recognized as a global issue (Bates *et al.*, 2008). At present due to anthropogenic activities like industrialization, deforestation and automobiles etc. changes in the climate are being taken place, which will again turn detrimental to life (Rakshit *et al.*, 2009). The earth temperature has been increasing year after year and the main root cause of rising earth's temperature is the climate change. The mean annual temperature of India is increased by 0.46^0 C over a period of last 111 years since 1901 (24.23^0 C) to 2012 (24.69^0 C) (Data Portal India, 2013).

Global combined surface temperatures over land and sea have been increased from 13.68^0 C in 1881-90 to 14.47^0 C in 2001-10 (WMO, 2013).Increase in gases such as CO_2, CH_4 and nitrous oxide (greenhouse gases) induces high temperature. This temperature increase will alter the timing and amount of rainfall, availability of water, wind patterns and causes incidence of weather extremes, such as droughts, heat waves, floods or storms, changes in ocean currents, acidification, forest fires and hastens rate of ozone depletion (Minaxi *et al.,* 2011; Kumar, 2012).

Climate change may have more effect on small and marginal farmers, particularly who are mainly dependent on vegetables (FAO, 2009). Vegetables is considered as protective foods because of ability to prevent diseases by supplying vitamins and minerals and moreover itsnutritional quality is determined by Soil factors, temperature, light and CO_2 so, a little change in these parameter will bring a drastic change in the quality there by the nutritional value of the vegetables may be reduced or increased for example increase in the level of CO_2 improved the vitamin C, sugars, acids and carotenoids in tomatoes. High-temperature stress has been reported to decrease vitamin C, starch, sugars and many antioxidants especially anthocyanins and volatile flavour compounds in fruits. It has also been reported that climatic fluctuations are known to affect post-harvest quality of vegetables and cause severe losses and affect food safety during storage, for example by causing changes in populations of aflatoxin-producing fungi (Cotty and Jaime-Garcia, 2007). The more frequent extreme weather events under climate change may damage infrastructure, with damaging impacts on storage and distribution of vegetables (Costello *et al.,* 2009). Besides low yields, change in nutritional quality, severe post-harvest losses,the climate change also affect the pest and disease incidence, host-pathogen interactions, distribution and ecology of insects, time of appearance, migration to new places and their overwintering capacity. In general, climate change has the potential to modify host physiology and resistance and to alter stages and rates of development of the pathogen (Coakley *et al.,* 1999).

In this review the impact of only major climatic factors on vegetable production has been discussed below.

Temperature

All vegetable needs an optimum temperature for their proper growth and development, but optimum temperature required varies from crop to crop in addition to this, temperature limits the range and production of many crops. With changing climate the crop will be exposed to increased temperature stress. The high temperature can affect different solanaceous crops in different ways. Among the vegetable crops potato will be adversely affected by climate change. Potato required exact temperature and day length for tuber formation and flowering, so it will be adversely affected by climate change. The effect of climate change on potato production in India has previously been studied by Singh *et al.,* (2009). Luck *et al.,* (2010) expected 16% decline in tuber yield of potato by 2050 for West Bengal if any special strategies are not adapted. An increase in temperature of above 21^0 C cause sharp reduction in the potato tuber yield, at 30^0 C complete inhibition of tuber formation occurs (Sekhawat, 2001).Tomatoes are strongly modified by temperature alone or in conjunction with other environmental factors (Abdalla and Verkerk, 1968). In tomato high temperature influence the photosynthetic functions of plants and causes lack of opening of the stromium, irregularities in the epidermis and endothesium and poor pollen formation. Pre- anthesis temperature stress is associated with development, change in the anther, particularly irregularities with the epidermis and endothesium, lack of opening of strontium and poor pollination (Sato and Thomas, 2002). Abnormal pollen production, abnormal development of the female reproductive tissues, hormonal imbalances and lower levels of carbohydrates and lack of pollination are responsible for the poor reproductive performance of tomatoes at high temperatures (Peet *et al.,* 1997). Lurie *et al.,* (1996) reported high temperature inhibits ripening by inhibiting the accumulation of ripening related m-RNAs, thereby inhibits continuous protein synthesis including ethylene production, lycopene accumulation and cell-wall dissolution. Post pollination exposure to high temperature inhibits fruit setin pepper, indicating sensitivity of fertilization process (Erickson and Markhart, 2002). High temperature affects red colour development in ripen chilli fruits and also causes flower drop, ovule abortion, poor fruit set and fruit drop in chilli (Arora *et al.*, 1987).

Flynn *et al.*, (2002) found high percentage (90%) seed germination of chilli at 20^0 C and complete inhibition at 10^0 C indicating that fall in minimum temperatures affect seed germination in chilli.The duration of onion gets shortened due to high temperature leading to reduced yields (Daymond *et al.*, 1997). In onion temperature increase above 40 ºC reduced the bulb size and increase of about 3.5ºC above 38ºC reduced yield (Lawande *et al.*, 2010).

Drought

Drought is the most important factor that cause famine and affect the world food security. Being succulent in nature vegetables are highly affected by water stress. High temperature coupled with low precipitation resulting from climate change will reduced the availability of irrigation water and at the same time evapotranspiration will be increased. So, this will leads to severe crop water stress resulting low yield and quality of vegetables. Drought increases the salt concentration in the soil and affects the reverse osmosis of loss of water from plant cells. This leads to an increased water loss in plant cells and inhibition of several physiological and biochemical processes such as photosynthesis, respiration etc., thereby reduces productivity of most vegetables (Pena and Hughes, 2007). The prevalence of drought conditions adversely affects the germination of seeds in vegetable crops like onion and okra and sprouting of tubers in potato (Arora *et al.*, 1987). Potato is highly sensitive to drought. A moderate level of water stress can also cause reductions in tuber yield (Jefferies and Mackerron, 1993). As succulent leaves are commercial products in leafy vegetables like amaranthus, palak and spinach, the drought conditions reduce their water content thereby reduces their quality (AVRDC, 1990). Chilli also suffers drought stress, leading to yield loss up to 50-60%.

Flooding

Vegetable production is also threatened by heavy rainfall. Flooding reduces the oxygen level in the root zone inhibiting aerobic processes. Under flooded condition tomato plants accumulate endogenous ethylene that causes damage to the plants. High temperatures coupled with flooding causes rapid wilting and death of plants. Floods can make the spread of water-borne pathogens easier, droughts and heat waves can predispose plants to infection, and storms can enhance wind-borne dispersal of spores (Pautasso *et al.*, 2012).

Salinity

Elevated soil salinity is very threatening to the vegetable production particularly in irrigated croplands and its main root cause is the drought. 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. Onions are susceptible to saline soils, while cucumber, eggplant, pepper, and tomato are moderately sensitive to saline soils (Pena and Huges, 2007). Salinity causes a significant reduction in germination percentage, germination rate, and root and shoots length and fresh root and shoot weight in cabbage (Jamil and Rha, 2004). Salinity reduces the tuber yield in potato. The combined stress of salinity and heat results in failure of vegetative growth recovery and a consequent reduction in the leaf area index and canopy functioning due to the damage of salt accumulation avoiding mechanism in young expanding leaves of potato (Bustan *et al.,* 2004). Salinity reduces dry matter production, leaf area, relative growth rate and net assimilation rate but increases leaf area ratio in chilli. The number of fruits per plant is more affected by salinity than the individual fruit weight (Lopez *et al.*, 2011). High salt concentration causes a reduction in fresh and dry weight of all cucurbits. These changes are associated with a decrease in relative water content and total chlorophyll content (Baysal *et al.*, 2004).

Table.1 Some varieties of vegetables to mitigate the harmful effect of heat and cold

S. No	Crop	Varieties	Tolerance
1	Tomato	PusaSadabahar, PusaSheetalPusa Hybrid-1	Tolerant to high and low temperatures
2	Radish	PusaChetki	Better root formation under high temperature regime, i.e. April-August
3	Carrot	PusaVrishti	Form root at high temperature and high humidity i.e. March-August
4	Early cauliflower	PusaMeghna	can form curd at high temperature

Table.2 List of some variety and advanced line tolerant to abiotic stress

S. 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, ArkaAmogh, ArkaSoumya	
		Cowpea	ArkaGarima, ArkaSuman, ArkaSamrudhi	IIHR Sel.-16-2
3	High temperature	Capsicum		IIHR Sel.-3
		French bean		IIHR-19-1
		Peas		IIHR-1 and IIHR-8
		Cauliflower		IIHR 316-1 and IIHR371-1

(Source: Rai and Yadav, 2005).

CO_2

Elevated CO_2 has positive effect ranging from 24-51% on productivity of vegetable crops. It has been reported that the horticultural crops having C_3 photosynthetic metabolism have shown beneficial effects indicated the increase in onion yield by 25-30% mainly due to increase in bulb size at 530 ppm CO_2 (Wurr *et al.*, 1998; Wheeler, 1996;Daymond*et al.*, 1997). Potato plants grown under elevated CO_2 may have larger photosynthetic rates up to some extent, later on with increase in CO_2 concentration the photosynthetic rates will come down (Burke *et al.*, 2001). The high atmospheric CO_2 content inhibits tomato fruit ripening. This inhibition is due to the suppression of the expression of ripening associated genes, which is probably related to the stress effect exerted by high CO_2 (Rothan *et al.*, 1997). The elevated CO_2 concentration has been reported to reduce chlorophyll content in leaves particularly during later growing season after tuber initiation (Bindi *et al.*, 2002; Lawson *et al.*, 2002).

Adaptation strategies and mitigation to climate change

Adoption of effective and efficient measure is the only way to mitigate the adverse impact of climate change on vegetable production and particularly on their productivity, quality and yield. Developing cultivars tolerant to heat and salinity stress and resistant to flood, change in the sowing date, use of efficient technologies like drip irrigation, soil and moisture conservations measures, fertilizers management through fertigation, use of grafting techniques, use of plant regulators, protected cultivation, improving pest management are the effective adaptations strategies for reducing the impact of climate change.

Resource conservation techniques and organic farming are the other mitigation measures which can be followed. Unlike agricultural crops most of the annual vegetables crops do not have any carbon sequestration potential, therefore scope for reducing emissions in their cultivation is highly limited and moreover the information on these aspects is lacking. Germplasm of major vegetable crops, which are tolerant to high temperatures, flooding and drought have been identified and advanced breeding lines are being developed in many institutions (Tables 1 and 2). Efforts are also underway to identify nitrogen-use efficient germplasm.

In Conclusion, Vegetables are more vulnerable to climate change, as it hampers production, quality and productivity. Effects of temperature generated by global warming on crop plants are the major among all the climate change effects. It is again responsible for other stresses like moisture stress, salinity and atmospheric gases like CO_2 concentration. Missionary approaches like development of production system, improved varieties with improved water use efficiency as well as tolerance to different biotic and abiotic stresses are taken up to mitigate the effects of climate change on vegetable production.

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