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Review Research Paper

Effects of Climate Change on Vegetable Cultivation - A Review

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ABSTRACT

World population is increasing at an alarming rate and is expected to reach about six billion by the end of year 2050. Increased hunger and malnourishment are challenging issues for all nations, especially those who are resource poor. Feeding of hunger-laden people of the world not only requires food in quantity but quality as well. Vegetables are protective foods embedded with vitamins, micronutrients, pharmaceutical and nutraceutical compounds, which are necessary for correction of diseases and disorders. Moreover, cultivation of vegetables provides livelihood security through employment. But the complex process of growth and development is significantly affected by different agro-climatic factors and therefore, any environmental aberration due to climate change can impose unprecedented stress on this group of plants which may lead to complete failure of the crop in a grower's field. Usually extreme temperatures, limited soil moisture, reduced availability of irrigation water, repeated flooding, increased acidity or salinity and soil erosion, high wind speed, increase in occurrence of hails and thunderstorms, frost damage and tsunamis etc., are the major limiting factors for optimum productivity besides the quality and consumer acceptance. Sudden change in climate also influences the status of soil fertility, occurrence of pests and diseases, host-pathogen interactions, soil microbial population and behaviour of the pollinators. Reduced production and productivity due to the development of genetically weakened seeds is the ultimate outcome of climate change which may invite a crisis in food reserve in the future. All these have significant effects on the total vegetable cultivation system on the planet, affecting the economic yield, which is of prime importance from grower's point of view. Hence, there is a need to develop an understanding of the impacts and implications of climate change on vegetable cultivation for timely intervention to ameliorate its harmful effects.

INTRODUCTION

The importance of vegetables in providing food and nutritional security and amelioration of nutrient deficiencies has been realised world over (Prasad et al. 2014). They also provide opportunities for higher farm income apart from livelihood security through employment generation. The worldwide production of vegetables has gone up tremendously during the last two decades and the value of global trade in vegetables now exceeds that of cereals (Dhiman 2012). It is a challenging issue to the most of nations to feed hunger-laden people. IFAD (International Fund for Agriculture Development) (2009) has reported that climate change is expected to put 49 million additional people at risk of hunger by 2020, and 132 million by 2050 (Devendra 2012). Hence, more emphasis is being given in the developing countries like India to promote cultivation of vegetables. World geographical areas comprise of mountains, coastal regions, deltas and different climatic conditions like temperate, tropical, sub-tropical, arid and humid zones etc. which are vulnerable to climate change. Little change in the climate will disturb the whole ecology and in-turn the traditional pattern of growing vegetables in these regions (Bhardwaj 2012). Degradation of land, extreme geophysical events and reduced water availability, are the factors which affect the vegetable production. Climate change refers to a change in the state of climate that can be identified by (e.g., by using statistical tests) changes in the mean of the various climatic parameters, such as temperature, precipitation, relative humidity and atmospheric gases composition, etc. and/or the variability of its properties, and that persists for an extended period, typically decades or longer in larger geographical areas (Cubasch et al. 2013). UNFCC defined climate change as a change of climate which is attributed directly or indirectly to human activity or due to natural variability. Vegetables are generally sensitive to environmental extremes. Extreme variation in temperature and limited soil moisture are the major causes of low yields as they greatly affect several physiological and biochemical processes like reduced photosynthetic activity, altered metabolism and enzymatic activity, thermal injury to the tissues, reduced pollination and fruit set etc. These will further be magnified by climate change which can exact a heavy toll on the vegetable production. Under changing climatic situations, crop failures, shortage of yields, reduction in quality and increasing pest and disease problems are common, which render the vegetable cultivation unprofitable (Koundinya et al., 2014). In India, potato production under the impact of climate change and global warming may decline by 3.16% and 13.72 % in the year 2020 and 2050, respectively (Sing et al. 2009). Yield potential of majority crops in this group are seriously affected by various climatic vagaries like development of high temperature, low temperature (chilling & freezing) in the atmosphere, occurrence flood, drought, salinity, soil erosion, storm, wind, hail damage, volcanic eruption and tsunamis etc., the summarized impact of these environmental extremes on vegetable cultivation is given below.

IMPACTS OF CLIMATE CHANGE ON VEGETABLES PRODUCTION

High temperature: 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 epithesium and endothesium, lack of opening of the stromium, and poor pollen formation (Peet et al. 1988, Sato et al. 2002). 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 & Markhart 2002). The cell membrane permeability and proline (heat tolerance index) content increased slightly under high temperature stress in Chinese cabbage cultivars (Datta 2013). Increased temperatures also reduce yield by affecting factors such as the sprouting of seed tubers, growth rates and tuberization, and each of these factors may be controlled by different genes (Peet & Wolfe 2000). Sudden development of high temperatures during the growing phase of lettuce and celery cause bolting (premature seed head production), resulting in poor quality heads, and reduced yields. In warm climate, survivalence of DBM (Diamond Back Moth) increases. Due to climate change they can affect the brassica growing regions, particularly the sub-tropical regions, and increasingly so in temperate regions. Under arid conditions, in the future, thrips will reproduce and survive more easily. Higher temperatures will have negative effects on survivability and reproduction of some important parasites and predators, e.g. Trichogramma in vegetables (Peter 2008).

Low temperature: Low temperature like chilling and freezing injury can occur in all plants, but the mechanism and types of damage vary considerably (Table 1). Damage due to exposure of the plant above 0°C (0°C-10°C) is chilling injury and slight exposure to less than 0°C is freeze injury. Freeze injury occurs in all plants due to rupture of the cell wall and destruction of cytoplasmic constituents as ice crystals are formed from cytoplasmic water. Crop plants that develop in tropical climates, may experience serious freezing injury, even occurrence of small freezing conditions, whereas most of the crops that develop in colder climates often survive with little freezing if the freezing condition is not too severe. In this regard, lettuce is exceptional as it has originated in a temperate climate but even a temperature near 0°C is extremely detrimental for it's survival. Exposure to chilling temperature in temperate climate may lead to a severe reduction of yield or complete crop failure due to either direct damage or delayed maturation. Even a small drop in temperature, causing no visible damage to chilling-sensitive plants, may cause up to 50% reduction in their productivity (Kopanh 1969). Low temperatures (decreases to 8-12°C.) have been reported to reduce seed germination and growth speed of pollen tube and the percent of fruit set of tomato (Pardossi et al. 1988). Growth reduction of muskmelon (reticulates group) (Risse et al. 1978) and watermelon (Bradow 1990, Hassell 1979). Seeds are especially (beans) sensitive to low temperatures during imbibitions and may not germinate at low temperatures.

Flooding: Most of the vegetables are highly sensitive to flooding, especially those who are shallow rooted. Under waterlogged conditions, the roots strive for oxygen as soil air is replaced by inundating water. Thus suffocation hampers root respiration seriously to maintain their usual activities of nutrient and water uptake. This leads to necrosis of root inviting infection with soil-borne pathogens (Andrew Puglis, Dennis Decoteau 1998). It was observed that flooded tomato plants accumulate endogenous ethylene (Table 2) that causes damage to the plants (Drew 1979). 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 (Kawase 1981). Further reports (Barclay & Crawford 1981, Patel et al. 2014) indicated that an internal ethanol concentration of 60 m mol/L appeared to be the threshold value for the survival of pea seedlings, and that anoxic death occurred when this concentration was exceeded. 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). ABA concentrations were found to increase in the roots of pea plants during the 2nd, 3rd and 4th days of flooding, causing stomata to partially close due to accumulation of ABA in the leaves (Zhang & Davies 1987). CO_2 used during photosynthesis first must pass through stomata into internal spaces within the leaf, then it diffuses into mesophyll cells where it becomes available for photosynthesis. When the stomata close, CO_2 levels drop rapidly within the leaf, inhibiting the light-independent reactions. This then causes photosynthesis to stop. Flooded soils of sweet potato (*Ipomea batatas* L.) caused losses due to rotting at harvest and increased shrinkage in storage (Thompson et al. 1992, Ton & Her-nandez 1978) besides losses in carotenoid pigments, dry matter content, and baking quality (Constantin et al. 1974). A study by Igwilo & Udeh (1987) on water logging effects on yam (*Dioscorea* spp.) vines for 24, 48, and 72 h indicated a progressive degeneration of the leaf starting with the development of fresh lesions on the lower leaves, through necrotic spots, to complete leaf necrosis. The degree of damage increased with the duration of water logging and damage was more severe in younger plants compared to the older plants. Pepper (*Capsicum annum* L.) is sensitive to prolonged flooding. Continuous flooding of pepper plants for 4 weeks resulted in poor growth, yellowing of leaves, blackening of the root tips, and a distinct swelling at the junction of the shoot and the roots (Hasnain & Sheik 1976) caused by decreased O_2 supply, decreased N uptake by roots, and the development of cortical cells. Flooding asparagus (*Asparagus officinalis* L.) plants continuously for 48 h after 2 and 3 weeks after transplanting, delayed the growth and reduced the survival of the transplanted seedlings when compared to two 8-h flooding separated by a 16-h period of drainage (Falloon et al. 1991).

Drought: Drought is defined as a long period of abnormally low rainfall, especially one that adversely affects growing or living conditions (Allaby 1989). Unpredictable drought is the single most important factor affecting world food security and the catalyst of the great famines of the past (CGIAR 2003). Vegetables, being succulent products by definition, generally consist of greater than 90% water (AVRDC 1990). Thus, water greatly influences the yield and quality of vegetables; drought conditions drastically reduce vegetable productivity. Drought stress causes an increase of solute concentration in the environment (soil), leading to an osmotic flow of water out of the plant cells. This leads to an increase of the solute concentration in plant cells, thereby lowering the water potential and disrupting membranes and cell processes such as photosynthesis. The timing, intensity, and duration of drought spells determine the magnitude of the effect of drought (Peña & Hughes 2007). (Kirnak et al. 2001) found that water stress results in significant decrease in chlorophyll content, electrolyte leakage, leaf relative water content and vegetative growth; and plants grown under high water stress have less fruit yield and quality. 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 & Mackerron 1993). Tomatoes are very sensitive to water deficits during immediately after transplanting, at flowering and fruit development (Nuruddin 2001). Root and bulb crops like potato, carrot, and onion crop yields depend on the production and translocation of carbohydrates from the leaf to the root or bulb (storage organ). Occurrence of drought stress during enlargement of storage organs reduces yield and quality. Cucumbers, melons, pumpkins and squashes, lima beans, snap beans, peas, peppers, sweet corn, and tomatoes are most sensitive to drought stress at flowering and as fruits and seeds develop. Fruit set on these crops can be seriously reduced if water becomes limited (Anonymous). Leafy vegetables like amaranthus, palak and spinach are succulent in nature; the drought condition reduces the water content in produce, which leads to poor quantity and quality (AVRDC 1990).

Salinity: Vegetable production is threatened by increasing soil salinity particularly in irrigated croplands which supply 40% demand of the food in the world (FAO 2001). In hot and dry environments, high evapotranspiration results in substantial water loss from soil, 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 (Yamaguchi & Blumwald 2005). Plant sensitivity to salt stress is reflected in the loss of turgor, reduction in growth, wilting, leaf curling and epinasty, leaf abscission, decreased photosynthesis, change in respiration, loss of cellular integrity, tissue necrosis, impaired seed germination, reduced nodule formation, retardation in plant development and a reduction in crop yield and even death of the plant (Jones 1986, Cheeseman 1988). According to the United States Department of Agriculture (USDA), onions are sensitive to saline soils, while cucumbers, eggplants, peppers, and tomatoes, amongst the main crops are moderately sensitive (Bharadwaj 2012). Under the influence of salt stress, growth of many species of vegetables is reduced, such as tomato (Romero-Aranda et al. 2001, Maggio et al. 2004), pepper (De Pascale et al. 2003b), celery (De Pascale et al. 2003a) and peas (Maksimovic et al. 2008, Maksimovic et al. 2010). Salt stress causes anatomical modifications in many vegetables, the epidermis and mesophyll cells of bean leaves become thick (Longstreth & Nobel 1979, reviewed Ivana Maksimovic & Žarko Ilin 2012). The adverse effect of salt stress causes a reduction in intercellular spaces in spinach leaves due to the presence of salt (Delfine et al. 1998) and increased stomatal density in pea (Maksimoviæ et al. 2010).

Table 1: The list of the vegetables, sensitive to chilling temperatures, the lowest safe storage/handling temperature and the symptoms of chilling injury (DeEll 2004).

Crop	Lowest safe temperature °C	Chilling injury symptoms
Asparagus	0-2	dull, gray-green, limp tips
Bean(snap)	7	pitting and russeting
Cucumber	7	pitting, water-soaked lesions, decay
Eggplant	7	surface scald, *Alternaria* rot, seed blackening
Okra	7	discoloration, water-soaked areas, pitting, decay
Pepper	7	pitting, *Alternaria* rot, seed blackening
Potato	7	mahogany browning, sweetening
Pumpkin	10	decay, especially *Alternaria* rot
Squash	10	decay, especially *Alternaria* rot
Sweet potato	10	decay, pitting, internal discoloration
Tomato(ripe)	7-10	water-soaking, softening, decay
Toamto (Mature-green)	13	poor colour when ripe, *Alternaria* rot

Increase in uptake and accumulation of Cl^- is accompanied by a reduction in the concentration of NO_3^- in eggplant (Savvas & Lenz 2000). High salt concentration causes a reduction in fresh and dry weight, relative water and total chlorophyll content (Baysal et al. 2004) of all cucurbits.

Frost: Frost injury occurs when ice forms inside the protoplasm of cells (intracellular freezing) and injures the plant cells. It can occur in annuals (legumes of forage and root crops) multi-annuals and perennials (deciduous and evergreen perennial vegetable trees). Frost damage may have a drastic effect upon the entire plant or affect only a small part of the plant tissue, which reduces yield, or merely product quality. Resulted of frost damage on different vegetables indicated in Table 3.

SOIL EROSION, STROM, WIND, HAIL DAMAGE, VOLCANIC ERUPTION AND TSUNAMI

Soil erosion causes negative effects that cannot be quantified easily. Erosion of soil from the root zone causes lodging of plants which is more harmful to most of the vegetables (tomato, egg plant, chilli, etc.). Damage of vegetable crops due to storm and further recovery of the crop will depend on a number of factors including the type of vegetable, stage of growth, weather conditions immediately after storms, and prevalence of disease organisms. Continued hot and moist condition after the storm is very detrimental which increases disease incidence, particularly bacterial diseases (Gordon Johnson 2013). Fruit bruising or wounding often causes the most severe losses in crops such as tomatoes. Fruits may be rendered unmarketable or of reduced grade. Wounds can also increase the incidence of some fruit diseases and storage rots. A report from Netherlands indicated that by 2050 annual hailstorm damage to outdoor farming could increase by between 25% and 50%, with considerable larger impacts on greenhouse horticulture in summer (more than 200%) (Sing et al. 2009). Sweet corn is more susceptible to loss of leaf area from the hail at tasseling and silking stage than any other in its life cycle. In general, complete loss of leaf area at this stage results in nearly 100% yield loss (Ritchie et al. 1997). Volcanic eruption generates numerous pollutants like SO_2 and other nitrogenous oxides which can destroy the plants nearby. Both of them are highly toxic to the vegetation. Tsunamis are natural disasters and its occurrence cause inundation of low lying areas with saline water near the shoreline which eventually suffers from severe salinization, harmful for salt sensitive vegetables like (potato, sweet potato, brinjal, radish and peas).

IMPACT OF CLIMATE CHANGE ON POLLINATING AGENTS AND POLLINATION BEHAVIOUR

Pollination is a crucial stage in the reproduction of most flowering plants, including vegetable crops (Kearns et al. 1998). Change in the climate may be threatening to pollination activities due to altered behaviour of pollinating agents (Memmott et al. 2007, Hegland et al. 2009, Schweiger et al. 2010). Among all the climatic factors, an increase in temperature has the highest adverse effect on pollinator interactions. Warming may actually enhance the performance of insects living at higher altitudes, thereby resulting in increased seed setting and yields in the temperate crops growing in these areas. But, rise in temperature in low lying hills adversely affects the activity of pollinating agents and hence lower seed yield. Climatic change, including global warming and increased variability of environmental hazards require improved analyses that can be used to assess the risk of the existing and the newly developed pollinators management strategies and techniques, and to define the impact of these techniques on environment, productivity and

Table 2: Summary of the influence of flooding duration and growth stage on tomato crop response (Renuka Rao & Yuncong Li 2003).

Duration	Stage	Response
24 h (hours)	6-7 leaf stage	Increase in ethylene production rate; leaf water potentials increased, stomatal closure and reduced transpiration, leaf epinasty.
24 h	9 week stage	Pronounced epinastic curvature of the petioles due to ethylene accumulation and production.
3d (days)	1 month	Reduced Stem growth and leaf chlorophyll content; increase in epinastic curvature of leaf petiole and adventitious roots.
10d	Seedling, flowering, fruiting	Greatest sensitivity was at the flowering stage. Overall, reduced plant height, leaf area, chlorophyll, respiration rate, percent survival, fruit set, total yield, seed set and dry weight of the plants.
1 month	1 month	Cessation of leaf elongation, leaf epinasty. Formation of adventitious roots, stomatal closure and reduced gaseous exchange.
36 h	1 month	Reduced flow of nitrate, hydrogen ions, most protein amino acids, glutamine, and abscisic acid to the shoots.
72 h	Flowering	Decrease in leaf water potentials and increase in adventitious roots.
8d	Fruiting	Induced stomatal closure, hastened fruit maturation, reduced internal fruit firmness and subsequently reduced the storage quality of fruit.
24 h	Flowering	Wilting of 15% of tomato plants (versus 4% for no waterlogged plants) and 40% yield reductions.

Table 3: Frost damage symptoms for vegetable crops (Caplan 1988).

Crop	Symptoms
Artichoke	Epidermis becomes detached and forms whitish to light tan blisters. When blisters are broken, underlying tissue turns brown.
Asparagus	Tip becomes limp and dark and the rest of the spear is water soaked. Thawed spears become mushy.
Beet	External and internal water soaking and sometimes blackening of conductive tissue.
Broccoli	The youngest florets in the centre of the curd are most sensitive to freezing injury. They turn brown and give off strong odour.
Cabbage	Leaves become water soaked, translucent and limp. Upon thawing the epidermis separates.
Carrot	Blistered appearance, jagged length-wise cracks. Interior becomes water soaked and darkens upon thawing.
Cauliflower	Curds turn brown and have a strong off-odour when cooked.
Celery	Leaves and petioles appear wilted and water soaked upon thawing. Petioles freeze more readily than leaves.
Garlic	Thawed cloves appear greyish yellow and water soaked.
Lettuce	Blistering of dead cells of the separated epidermis on outer leaves, and become tan with increased susceptibility to physical damage and decay.
Onion	Thawed bulbs are soft, greyish yellow and water soaked in cross- section. Damage is often limited to individual scales.
Bell Pepper	Dead, water-soaked tissue in part or all of pericarp surface with pitting, shriveling and decay.
Potato	Freezing injury may not be externally evident, but shows as grey or bluish-grey patches beneath the skin. Thawed tubers become soft.
Sweet potato	A yellowish-brown discoloration of the vascular ring and a yellowish green, water-soaked appearance of other tissues. Roots soften and become susceptible to decay.
Tomato	In partially frozen fruits, the margin between healthy and dead tissue is distinct, especially in green fruits.

profitability (Lee et al. 2009). Many bee species are able to control the temperatures in their flight muscles before, during and after the flight, by physiological and behavioural means (Willmer & Stone 1997). With respect to the potential effects of future global warming, behavioural responses of pollinator to avoid extreme temperatures have the potential effect on significant reduction of pollination services (Corbet et al. 1993). Examples of behavioural strategies for thermal regulation include long periods of basking in the sun to warm up and shade seeking or nest returning to cool down, which reduces the floral visiting time of pollinators, thereby subsequent pollination and fruit or seed set (Willmer & Stone 2004).

CONCLUSION

Climate change is a continuous process. An overall idea on the effects of climate change will provide better diagnosis and this is the primary tool to take further steps for mitigation. It is high time to realise the sensitivity of climate, which is adversely effected either environmentally (naturally) or through human intervention. According to previous studies, it was revealed that magnitude of climate change is most sensitive to anthropogents which directly or indirectly induce environmental aberrations like floods, drought, salinity, high temperature, etc., apart from shifting of cropping seasons, growth and yield patterns, pest and disease scenario and pollinating behaviour of insects. It is clearly indicated that, severe threat is ahead generating cautions for crises of food and nutrition, employment and livelihood security, leading to poverty in future. Complete eradication of climatic change effects is not possible, but minimization of it is evitable through sincere intervention. There must be a goal of nations to formulate global strategy to take a missionary approach. According to authors opinion, it is high time to take small but sincere efforts by each individual or group for reduction of the climate change so that the nature God can take care of its living entities on the earth.

REFERENCES

Allaby and Michael 1989. Dictionary of the Environment. Third edition, New York University Press.

Aloni, B. and Rosenshtein, G. 1982. Effect of flooding on tomato cultivars: The relationship between prolin accumulation and other morphological and physiological changes. Physiologia Plantarum, 56(4): 513-517.

Arora, S.K., Partap, P.S., Pandita, M.L. and Jalal, I. 1987. Production problems and their possible remedies in vegetable crops. Indian Horticulture, 32(2): 2-8.

AVRDC 1990. Vegetable Production Training Manual. Asian Vegetable Research and Training Center, Shanhua, Tainan, pp. 447.

Barclay, A.M. and Crawford, R.M.M. 1981. Temperature and anoxic injury in pea seedlings. J. Exp. Bot., 32(5): 943-949.

Bhardwaj, M.L. 2012. Challenges and opportunities of vegetable cultivation under changing climate scenario. A Training Manual on Vegetable Production Under Changing Climate Scenario.

Bhardwaj, M.L., Dev Sharma, H., Manish Kumar, Ramesh Kumar, Sandeep ansal, Kuldeep Thakur, Shiv Pratap Singh, Dharminder Kumar, Santosh Kumari, Meenu Gupta and Vipin Sharma, 2012. A Training Manual on Vegetable Production Under Changing Climate Scenario.

Botzen, W.J.W., Bouwer, L.M. and Van den Bergh, J.C.J.M. 2009. Climate change and hailstorm damage: Empirical evidence and implications for agriculture and insurance. Resource and Energy Economics, 32(3): 341-362.

Bradow, J.M. 1990. Chilling sensitivity of photosynthetic oil-seedlings. J. Expt. Bot., 41: 1595-1600.

Caplan, L.A. 1988. Effects of cold weather in horticultural plants in Indiana. Purdue University Cooperative Extension Publication.

CGIAR 2003. Applications of molecular biology and genomics to genetic enhancement of crop tolerance to abiotic stresses-a discussion document. Interim Science Council Secretariat, FAO.

Cheeseman, J.M. 1988. Mechanisms of salinity tolerance in plants. Plant Physiol., 87: 57-550.

Constantin, R.J., Hernandez, T.P. and Jones, L.G. 1974. Effect of irrigation and N fertilization on quality of sweet potatoes. J. Amer. Soc. Hort. Sci., 99: 308-310.

Corbet, S.A., Fussell., M., Ake, R., Fraser, A., Gunson, C., Savage, A. and Smith, K. 1993. Temperature and the pollinating activity of social bees. Ecol. Entomol., 18: 17-30.

Cruz, R.V., Harasawa, H., Lal., M., Wu, S., Anokhin, Y., Punsalma, B., Honda, Y., Jafari, M., Li, C. and Huu Ninh, N. 2007. Asia, Climate Change 2007: Impacts, Adaptation and Vulnerability. Fourth assessment report of the intergovernmental panel on climate change. Cambridge University Press, Cambridge, pp. 469-506.

Cubasch, U., Wuebbles, D., Chen, D. and Facchini, M.C., Frame, D.N., Mahowald and Winther J.G. 2013. Introduction. In: Climate Change 2013: The Physical Science Basis, Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.), Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Datta, S. 2013. Impact of climate change in Indian horticulture - a review. International J. of Sci., Environ. and Tech., 2(4): 661-671.

De Pascale, S., Maggio, A., Ruggiero, C. and Barbieri, G. 2003a. Growth, water relations, and ion content of field grown celery under saline irrigation (*Apium graveolens* L. var. *dulce* [Mill.] pers.). J. of the Ame. Soci. for Hort. Sci., 128: 136-143.

De Pascale, S., Ruggiero, C., Barbieri, G. and Maggio, A. 2003b. Physiological response of pepper (*Capsicum annuum* L.) to salinity and drought. J. of the Ame. Soci. for Hort. Sci., 128: 48-54.

DeEll, J. 2011. Symptoms of chilling injury in vegetables. Ontario Ministry of Agriculture Rural Affairs 2004. http://www.omafra.gov.on.ca/english/crops/hort/news/hortmatt/2004/18hrt04a5.htm

Delfine, S., Alvino, A., Zacchini, M. and Loreto, F. 1998. Consequences of salt stress on conductance to CO_2 diffusion, Rubisco characteristics and anatomy of spinach leaves. Aus. J. of. Plant. Physio., 25: 395-402.

Dennis Decoteau. Plant Physiology: Environmental factors and Photosynthesis. Greenhouse Glazing & Solar Radiation Transmission Workshop, October 1998 © CCEA, Center for Controlled Environment Agriculture, Rutgers University, Cook College, pp. 1-6.

Devendra, C. 2012. Climate Change Threats and Effects: Challenges for Agriculture and Food Security. ASM Series on Climate Change. ISBN 978-983-9445-82-4.

Dhiman, 2012. A training manual on vegetable Production under changing climate scenario.

Drew, M.C. 1979. Plant responses to anaerobic conditions in soil and solution culture. Curr. Adv. Plant Sci., 36: 1-14.

Erickson, A.N. and Markhart, A.H. 2002. Flower developmental stage and organ sensitivity of bell pepper (*Capsicum annuum* L.) to elevated temperature. Plant Cell Environ., 25: 123-130.

Falloon, P.G., Greathead, A.S., Mullen, R.J., Benson, B.L. and Grogan, R.G. 1991. Individual and combined effect of flooding phytopthora rot and metalaxyl on asparagus establishment. Plant. Dis., 75: 514-518.

FAO 2001. Climate variability and change: A challenge for sustainable agricultural production. Committee on Agriculture, Sixteenth Session Report, 26-30 March, 2001, Rome, Italy.

Gordon Johnson 2013. Storm Damaged Vegetables-Wind and Hail. Cooperative Extension.

Hasnain, S. and Sheik, K.H. 1976. Effect of flooding and drainage on the growth of capsicum annuum. Biologia, 22: 89-106.

Hassell, R.L. 1979. The effects of low temperature on the growth of muskmelon and watermelon plants. MS Thesis, Cornell Univ., Ithaca, N.Y.

Hegland, S.J., Nielsen, A., Lázaro, A., Bjerknes, A.L. and Totland, O. 2009. How does climate warming affect plant pollinator interactions? Ecology Letters, 12: 184-195.

Hubbell, J.N., William, R.D., Lin, S.M., Roan, Y.S.C. and Hsu, H.A. 1979. Effect of excessive water, cultivar, compost, and BA and performance of tomato production on two soil types. In: R. Cowell (ed.). 1st Ind. Symp. Trop. Tomato. Asian Veg. Res. Deve. Ctr., Shanhua, Taiwan.

Igwilo, N. and Udeh, A.C.D. 1987. Effect of water logging yam vines on vegetative growth and tuber yield. Ann. Appl. Biol., 110: 391-398.

Ivana, Maksimovic and Žarko, Ilin. 2012. Effects of salinity on vegetable growth and nutrients uptake. Irrigation Systems and Practices in Challenging Environments, 9: 169-190.

Jefferies, R.A. and Mackerron, D.K.L. 1993. Responses of potato genotypes to drought. II. Leaf area index, growth and yield. Annals of Applied Biology, 122: 105-112.

Jones, R.A. 1986. The development of salt-tolerant tomatoes: breeding strategies. Acta Horticulturae. 190: Symposium on Tomato Production on Arid Land.

Karlen, D.L., Sojka, R.E. and Robbins, M.L. 1983. Indluence of excess soil-water and N rates on leaf diffusive resistance and storage quality of tomato fruit. Commun. Soil Sci. Plant Anal., 14(8): 699-708.

Kawase, M. 1981. Anatomical and morphological adaptation of plants to water logging. Hort. Science, 16: 30-34.

Kearns, C.A., Inouye, D.W. and Waser, N.M. 1998. Endangered mutualisms: the conservation of plant pollinator interactions. Annual Review of Ecology System, 29: 83-112.

Kirnak, H., Kaya, C., Tas, I. and Higgs, D. 2001. The influence of water deficit on vegetative growth, physiology, fruit yield and quality in eggplants. Bulg. J. Plant Physiol., 27(3-4): 34-46.

Koundinya, Ayyagari, Palash Sidhya and Pandit, M.K. 2014. Impact of climate change on vegetable cultivation - a review. Int. J. of Agr., Env. & Biotech., 7(1): 145-155.

Kuo, D.G., Tsay, J.S., Chen, B.W. and Lin, P.Y. 1982. Screening for flooding tolerance in the genus. Lycopersicon. Hort. Sci., 17(1): 76-78.

Lee, J.H., Stahl, M., Sawlis, S., Suzuki, S. and Lee, J.H. 2009a. A potential risk assessment of a dengue outbreak in North Central Texas, USA (Part 1 of 2): abundance and temporal variation of dengue vectors. J. of Env. Health, 71:24-29.

Lee, J.H., Stahl, M., Sawlis, S. and Suzuki, S. 2009b. A potential risk assessment of a dengue outbreak in North Central Texas, USA (Part 2 of 2): development of a practical prevention strategy. J. of Env. Health, 71:36-39.

Longstreth, D.J. and Nobel, P.S. 1979. Salinity effects on leaf anatomy. Plant Physio., 63: 700-703.

Lopez, M.V. and Del Rosario, D.A. 1983. Performance of tomatoes under water-logged conditions. Philippine J. Crop Sci., 8: 75-80.

Maggio, A., De Pascale, S., Angelino, G., Ruggiero, C. and Barbieri, G. 2004. Physiological response of tomato to saline irrigation in long-term salinized soils. Euro. J. of Agro., 21: 149-159.

Maksimoviæ, I., Beliæ, S., Putnik-Deliæ, M. and Gani, I. 2008. The effect of sodium concentration in the irrigation water on pea yield and composition. Proceedings of ECO Conference 2008, Novi Sad, pp. 231-235.

Maksimoviæ, I., Kastori, R., Krstiæ, L. and Lukoviæ, J. 2007. Steady presence of Cd and Ni affects root anatomy, accumulation and distribution of essential ions in maize seedlings. Bio. Planta., 51: 589-592.

Memmott, J., Craze, P.G., Waser, N.M. and Price, M.V. 2007. Global warming and the disruption of plant pollinator interactions. Eco. Letters, 10: 710-717.

Nuruddin, Md Molla 2001. Effect of water stress on tomato at different growth stages. M.Sc Thesis.

Pardossi, A., Vernieri, P., Tognoni, F. 1992. Involvement of abscisic acid in regulating water status in *Phaseolus vulgaris* L. during chilling. Plant Physiology, 100(3): 1243-1250.

Patel, P.K., Singh, A.K., Tripathi, N., Yadav, D. and Hemantaranjan, A. 2014. Flooding: Abiotic constraint limiting vegetable productivity. Adv. Plants Agric. Res., 1(3): 00016.

Pathak, H., Aggarwal, P.K. and Singh, S.D. 2012. Climate Change Impact, Adaptation and Mitigation in Agriculture: Methodology for Assessment and Applications. Indian Agricultural Research Institute, New Delhi, pp. xix + 302.

Peet, M.M. and Wolfe, D. 2000. Vegetable crop responses to climatic change. In: Reddy, K.R., Hodges, H.F. (eds.), Climate Change and Global Crop Productivity, CABI Publishing: Wallingford, UK., pp. 213-243.

Peet, M.M., Sato, S. and Gardner, R. 1998. Comparing heat stress on male-sterile and male-fertile tomatoes. Plant, Cell and Environment, 21: 225-231.

Peter Deuter, 2008. Garnaut climate change review. In: Defining the Impacts of Climate Change on Horticulture in Australia.

Prasad, B.V.G., Chakravorty, S., Deb, P. 2014. Food-nutritional and aesthetic security for future India by horticulture. Life Science Int. J., 1(1): 328-331.

R de la Peña and Hughes, J. 2007. Improving vegetable productivity in a variable and changing climate. Journal of SAT Agricultural Research, 4(1): 1-22.

Reid, D.M. and Railton, I.D. 1974. Effect of flooding on the growth of tomato plants: involvement of cytokinins and gibberellins. Bui. Royal Soc. N.Z., 789-792.

Renuka Rao and Yuncong, Li 2013. Management of flooding effects on growth of vegetable crops and selected field crops. Hort. Tech., 13(4).

Risse, G., Carnillon, P., Rode, J.C. and Auge, M. 1978. Effect de la temperature des racines sur la croissance de jeunes plants de diverse varieties de melon (*Cucumis melo* L.). Ann. Agron., 29: 453-473.

Ritchie, S.W., Hanway, J.J. and Benson, G.O. 1997. How a corn plant develops. Iowa State Univ. Coop. Ext. Serv. Spec. Rep., 48. Iowa State Univ., Ames.

Romero-Aranda, R., Soria, T. and Cuartero, J. 2001. Tomato plant water uptake and plantwater relationships under saline growth conditions. Plant Sci., 160: 265-72.

Sato Peet, M.M. and Thomas, J.F. 2002. Determining critical pre-and post-anthesis periods and physiological process in *Lycopersicon esculentum* Mill, exposed to moderately elevated temperatures. J. Exp. Bot., 53: 1187-1195.

Savvas, D. and Lenz, F. 2000. Effects of NaCl or nutrient-induced salinity on growth, yield, and composition of eggplants grown in rockwool. Sci. Hort., 84: 37-47.

Schweiger, O., Biesmeijer, J.C., Bommarco, R., Hickler, T., Hulme, P., Klotz, S., Kuhn, I., Moora, M., Nielsen, A., Ohlemuller, R., Petanidou, T., Potts, S.G., Pysek, P., Stout, J.C., Sykes, M., Tscheulin, T., Vila, M., Wather, G.R. and Westphal, C. 2010. Multiple stressors on biotic interactions: how climate change and alien species interact to affect pollination. Bio. Res., 85: 777-795.

Singh, J.P. and Lal, S.S. 2009. Climate change and potato production in India. In: Workshop Proceedings: Impact of Climate Change on Agriculture. ISPRS Archives XXXVIII-8/W3 115.

Steve Reiners 2006. Dealing with Flooded Vegetable Fields. Cornell University.

Thomposon, P.G., Smittle, D.A. and Hall, M.R. 1992. Relationship of sweet potato yield and quality to amount of irrigation water. Hort. Sci., 27(1): 23-26.

Ton, C.S. and Hernandez, T.P. 1978. Wet soil stress effects on sweet potatoes. J. Amer. Soc. Hort. Sci., 103: 600-603.

Willmer, P. and Stone, G. 1997. Temperature and water relations in desert bees. J. Thermal Biol., 22: 453-465.

Willmer, P.G. and Stone, G.N. 2004. Behavioral, ecological, and physiological determinants of the activity patterns of bees. In: Advances in the Study of Behavior, San Diego, CA, Elsevier Academic Press Inc., 34: 347-466.

Yamaguchi, T. and Blumwald, E. 2005. Developing salt-tolerant crop plants: challenges and opportunities. Trends Plant Sci., 10(12): 616-619.

Zhang, J. and Davies, W.J. 1987. ABA in roots and leaves of flooded pea plants. J. Exp. Bot., 38(4): 649-659.