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Review Paper

Effect of changing climatic scenario on vegetable production and mitigation strategies: a review

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ABSTRACT

It is estimated that nearly a third of global arable land has been lost to soil erosion and pollution during the past 4 decades. Vegetables in are general more sensitive to climatic extremes such as temperature fluctuations, biotic and abiotic stresses, reduced irrigation-water availability, flooding, drought, and salinity. Under changing climatic situations, crop failures, shortage of yields, reduction in quality, and increasing pest and disease problems are common, and they render vegetable cultivation unprofitable. It has been estimated that the number of pollinators has reduced due to combined stress from adverse climatic events and habitat loss. As many vegetables rely on pollinators, a complete loss of pollinators has been predicted to reduce vegetable supply by 16% (Smith *et al*., 2015). Therefore, reduced production and productivity invite a crisis in food reserve in the near future, and agriculture is faced with the challenge of food/nutritional security to meet the requirement for the ever-growing world population which is projected to reach approximately 9.7 billion in 2050. Hence, there is an urge to develop an understanding of the impacts and implications of climate change on vegetable production for timely intervention to ameliorate its negative effects. Farming practices such as planting of drought-resistant varieties of crops, crop diversification, change in cropping pattern and calendar of planting, improved irrigation efficiency, adopting soil conservation measures to conserve soil moisture, nutrient management, tillage/residue management, improved stress tolerance through grafting, developing climate-resilient vegetables, climate profiling through genomics and biotechnology, engineering stress tolerance, etc are to be practiced to boost sustainable production of vegetables to meet the challenges put forth by the global climatic change. Breeding strategies such as identifying and strengthening local breeds that have adapted to local climatic stress and feed sources and improving local genetics through cross-breeding with heat and disease tolerant breeds.

Keywords: Biotechnology, climate change, drought, genomics, salinity crop diversification, vegetable production

Climate change may be a change in the mean of the various climatic parameters such as temperature, precipitation, relative humidity and atmospheric gaseous composition etc. and in properties over a longer time 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. Global rise in temperature, changes in precipitation patterns, rise of sea levels, excess UV radiation and higher incidence of extreme weather events like droughts and floods and are already causing significant agricultural yield losses and will become even more prevalent in the coming decades due to the effects of global climate change (Battisti and Naylor, 2009). Over ten decades, an increased in the concentration of greenhouse gases (carbon dioxide, methane and nitrous oxide along with halogenated compounds) in atmosphere as of human exercises were recorded which directly affects the environment in the form of global warming (IPCC, 1997). Vulnerability of any system to climate change is the degree to which these systems are susceptible and unable to service 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 average global temperature has increased by 0.74ºC between 1906-2005 and a further increase of 0.2ºC to 0.4ºC in the next 20 years is expected, atmospheric CO2 will increase from the current concentration of 360 ppm to 400–750 ppm by 2100, sea level will rise from 15 cm to 95 cm by 2100(IPCC, 2007). The years 2016 and 2020 are tied for the warmest year on record {NASA's Goddard Institute for Space Studies (GISS) in New York.}. Global sea level rose about 8 inches (20 centimeters) since 19th century. The rate in the last two decades, however, is nearly double that of the last century and accelerating slightly each year. Average sea level rise is predicted as 24 - 30cm by 2065 and 1meter by 2100 (IPCC 2014). The Biggest Climate Change Events that occurred in 2021 include Rising Global Temperatures (2021 has been somewhere between the 5th and 7th warmest year on record globally so far); More Severe and Prolonged Heat Waves; Widespread and More Frequent Wildfires; Extreme Rainfall and Fatal Flash Floods; Record High Arctic Sea Ice and Glaciers Melt; Record Sea Level Rise(Global sea level rose an average of 4.4 mm per year between 2013 and 2021); Severe and Prolonged Droughts Extreme Tropical Cyclones; Cold Temperature Records. Also, one of the major events that took place because of the climate change was the infestation of locusts. Even as India grapples with the coronavirus pandemic, the country has been hit by a new pestilence in the form of large locust swarms as well. It was the biggest attack in close to 30 years, millions of locusts are swarming across western and northern India, destroying farms and raising alarm ahead of the main summer cropping season. Infestation of desert locusts, which has plagued a vast path from eastern Africa to India in recent years, is closely linked to climate change, experts said. The warming of the Indian Ocean due to climate change is cited as the main reason for the proliferation of locusts that are now ranging from the horn of Africa to the Arabian Peninsula to the Indian sub-continent. Locusts have been a misery especially to farmers in several countries, including India, Pakistan and Iran. Unusual rainfall in Iran helped in their breeding (Down to Earth Magazine, 2020). According to NASA, Greenland is losing around 286 billion tons of ice volume per year, Antarctica shreds about 127 billion tons of ice. With each decade, there's about 13% less ice cover. The volume of sea ice is less than half of what it was 2 decades ago. The largest impact of climate change is that it could wipe off up to 18% of GDP off the worldwide economy by 2050 if global temperatures rise by 3.2°C, the Swiss Re Institute warns. The impact of climate change has been forecasted to be the hardest hit for Asian economies, with a 5.5% hit to GDP in the best-case scenario, and 26.5% hit in a severe scenario. Between 2030 and 2050, climate change is expected to cause approximately 250 000 additional deaths per year, from malnutrition, malaria, diarrhea and heat stress (WHO-2021). The direct damage costs to health (i.e., excluding costs in health-determining sectors such as agriculture and water and sanitation), is estimated to be between USD 2-4 billion/year by 2030 (WHO-2021). 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).

In Kashmir snowfall has decreased as the winters are now warmer than two-three decades back in the Himalayas, lead to degradation of soil, rising temperature, erratic rainfall, unexpected frost and hailstorm, and emergence of new pests and diseases. In Jammu and Kashmir, there has been rise in temperature by about 0.4- 0.5 °C in Kashmir region and 0.3- 0.6°C in Jammu region. Due to the melting of glaciers, there occurs frequent floods, decrease in water availability in streams during summers. We have lost 18% of the Kolhoi Glacier, the main source of drinking water and irrigation in the valley, in the last 40 years. Kolahoi Glacier is a valley glacier in the north-western Himalayan Range situated 26 km north from Pahalgam and 16 km south from Sonamarg, in the union territory of Jammu and Kashmir. To its north flows the Sind River. Kolahoi Glacier is the source of water to Lidder River in the vicinity of Kashmir valley. This glacier has shrunk by 2.81 km^2 during the last 51 years (1962–2013) losing an ice volume of 0.30 km^3. Kashmir was blessed with the number of springs and streams but climate change led to drying up of springs and about two-third reduction in water level in almost all the streams and rivers of Kashmir during the last 4 decades (Ramshoo, 2017). As per INCCA assessment the number of rainy days in the Himalayan region in 2030s may rise by 5-10 days on an average, with an escalation by more than 15 days in the eastern part of the Jammu and Kashmir region. The intensity of rain fall is likely to increase by 1-2 mm/day. This is likely to impact some of the horticultural crops (Bilal 2019).

A significant change in climate on a global scale will impact agriculture and consequently affect the world's food supply. Climate change is not necessarily harmful; the problems arise from extreme events that are difficult to predict (FAO 2001). Erratic rainfall patterns and unpredictable high temperature spells will consequently reduce crop productivity. Developing countries in the tropics will be particularly vulnerable. Latitudinal and altitudinal shifts in ecological and agro-economic zones, land degradation, extreme geophysical events, reduced water availability, and rise in sea level and salinization are postulated (FAO 2004). Global climate change is emerging as one of the major constrains for world vegetable production. 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 as major threats for vegetable production. India's agriculture is more dependent on monsoon from the ancient periods, any change in monsoon trend drastically affects agriculture.

Impact of Climate change on Vegetables: Each plant has certain environmental requirements and therefore must be grown in such environmental conditions to attain the highest potential yield. A crop can be grown with minimal adjustments if it is well matched with its climate or growing condition. Unfavourable environmental conditions can produce a stress on plants resulting in lower yields. Vegetables being protective food embedded with vitamins, micronutrients, pharmaceutical and nutraceutical compounds, which are necessary for correction of diseases and disorders, play an important role in overcoming micronutrient deficiencies as well as assuaging poverty to millions of people. The different development stages of vegetable crops are highly sensitive to environmental extremes. 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 plants which may lead to complete failure of the crop in a grower's field. Extreme variation and fluctuation in temperature and limited soil moisture are the major causes of low yields as they greatly influence 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. Most of the vegetables are also sensitive to exposure of UV radiation as it harms photosynthesis, DNA, RNA, proteins and membranes. 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). Climate change plays an important role in increasing the range and races of pathogens, new type of viruses and insect vectors as genetic changes facilitated through mutation and recombination. A B-biotype whitefly introduced in Brazil that acts as vector of viruses in tomato having an ability to recombine and produce new viral diseases (Fernandes *et al*., 2006).

Thus, climatic change such as global warming changes in seasonal and monsoon pattern, biotic and abiotic factors render the vegetable cultivation unprofitable. Plant response to climate change is dictated by a complex set of interactions to CO2, temperature, solar radiation, and precipitation etc. Each crop species has a given set of temperature thresholds that define the upper and lower boundaries for growth and reproduction, along with optimum temperatures for each developmental stage. Currently crops are grown in areas in where they are exposed to temperatures that match their threshold values. As over the next century due to increase in temperature shifts may occur in crop production areas. Pollination is one of the most sensitive stages to temperatures, and exposure to high temperatures during this period can greatly decrease crop yields and increase the risk of total crop failure. Exposure of crops to warm night time temperatures during grain, fibre, or fruit production lowers the productivity and reduces quality as well. Increasing temperatures cause plants to mature and complete the developmental stages faster, which may alter the feasibility and productivity of regional crop rotations and field management options, including double-cropping and use of cover crops. Faster growth may create smaller plants, because soil may not be able to supply water or nutrients at required rates, thereby reducing grain, forage, fruit, or fibre production. Increasing temperatures also increase the rate of water use by plants, causing more water stress in areas with variable precipitation. Water stress together with increased temperature affects the yield and quality of vegetables as it reduces precipitation, hampers soil microbial activities and increases evapotranspiration results in desiccating effects and wilting of vegetable plants. Under waterlogged condition, small roots may form due to reduction of oxygen around the root zone. 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. Climatic variations are known to affect post-harvest life and quality of vegetables and cause severe losses and affect food safety during storage (Cotty and Jaime-Garcia, 2007). All these have substantial effects on the total vegetable cultivation system on the planet, affecting the economic yield, which is of chief 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.

Factors responsible for climate change: Climate change variables such as temperature, moisture and atmospheric composition may have a direct and indirect effect on the yield, occurrence of diseases and insect pests that ultimately influences the quality of crops. The severity of environmental stresses i.e., extreme temperatures, reduced water accessibility, water logging, salinity and other factors will be the main limiting factors in vegetable production.

The factors responsible for climate change and their effect on vegetable crops are illustrated below:

Temperature: Optimum temperature plays an important role in the growth and development of crops that ultimately affects their productivity. If vegetable grows under unfamiliar extreme high and low temperature, it restricts the production and productivity of crops (Tesfaendrias *et al*., 2013). Fluctuation in daily mean maximum and minimum temperature is the primary effect of climate change that adversely affects vegetable production, as many plant physiological, bio-chemical and metabolic activities are temperature dependent. Escalating 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. A fluctuation in the temperature particularly high temperature tends to increase in formation of tropospheric ozone that tend to cause oxidative stress for the crops. As a result, it reduces photosynthates that check the plant growth and development (Adebayo, 2010). Increased temperatures also reduce yield by affecting factors such as the sprouting of seed tubers, growth rates and tuberization, sudden development of high temperatures during the early growing phase of lettuce and celery cause bolting (premature seed head production), resulting in poor quality heads, and reduced yields. Hazra *et al* 2007, in tomato summarized the symptoms causing fruit set failure at high temperatures, this includes bud drop, abnormal flower development, poor pollen production, dehiscence, and viability, ovule abortion and poor viability, reduced carbohydrate availability, and other reproductive abnormalities. During temperature stress, pre-anthesis occurs and is related with irregularities in the endothecium and epidermis, poor pollen development, developmental changes in the anthers and lack of opening of the stromium (Sato *et al*., 2002). Erickson and Markhart, 2002 reported that high temperature exposure at the pre-anthesis stage in pepper did not affect viability of androecium and gynoecium, but under extreme post-pollination temperatures, a reduced percentage of fruit setting was noticed which indicates fertilization is sensitive to high temperature stress condition. They concluded that the high temperature exposure at a late-development, pre-anthesis stage did not affect pistil or stamen viability, but high post-pollination temperatures inhibited fruit set, suggesting that fertilization and post-pollination events are sensitive to high temperature and are responsible for decreased fruit set. Potato growth and development is affected at high temperatures. No potato crop growth is possible below 20°C and above 30°C. The minimum (0-7°C), optimum (16-25°C) and maximum (40°C) temperatures for net photosynthesis are reported. Potato requires cool night temperature to induce tuberization. Although photosynthesis in potato is suppressed by high temperature, it is not as sensitive to temperature as tuberization and partitioning of photosynthates to tuber. The radiation use efficiency (RUE) is suppressed under elevated temperatures. High temperature reduces tuber number and size (Ewing, 1997). Potato being very strict to its temperature requirement for tuber formation. Optimum tuber formation takes place at 20°C. An increase in temperature of above 21°C cause sharp reduction in the potato tuber yield, at 30°C complete inhibition of tuber formation occurs (Sekhawat, 2001).

Depending on varieties, cauliflower requires chilling treatment i.e., vernalisation that ranges from 9°C to 14°C for curd initiation (Grevsen and Olesen, 1994). Vernalisation process delays under high temperature, results in suspension of curd initiation and plants continued to produce leaves (Wurr *et al*., 1995). In a report, delayed curd initiation by up to 49 days and a greater number of leaves was observed due to an increase in temperature. Intense heat in dry months reduces the movement of pollinating agents, changes stigma-pollen interactions and quality of leafy vegetables under open conditions (Singh and Bainsla, 2015). An elevated temperature (35-45°C) in day hours cause denaturation and protoplast injury to cell death in tomato, sweet pepper, palak, lettuce and green onion. Many of the vegetable crops prone to extreme high temperatures causing flower damage, reduces fruit setting and pollen viability percentage (Hanson *et al*., 2011). Under warmer conditions, insects may produce variety of species and higher populations that attacks on more hosts in temperate conditions (Bale *et al*., 2002). With an increase in temperature of 2°C, the effectiveness of Colorado potato beetle, European corn borer, cabbage and onion maggot, increased to 1-5 supplementary life cycles per year (season) (Kiritani *et al.*, 1998). High temperature also favours the rapid reproduction of whitefly (Bemisia tabaci), acts as a source of vectors for the dispersion of many viral diseases and creates a major threat to solanaceous crops (Hanson *et al*., 2011). Flynn *et al*., (2002) found high percentage (90%) seed germination of chilli at 20°C and complete inhibition at 10°C indicating that fall in minimum temperatures affect seed germination in chilli. Also, 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). Tomatoes and pepper are also prone to viroids under high temperature. Due to climate change, fluctuation in temperature coupled with abundant soil moisture results in high evapotranspiration and an increase in microclimate of crops that alters the growth, development, pathogenicity and spread of pathogen as well. It also affects the geographical distribution, physiology and resistance of the both host plant and pathogens (Gautam *et al*., 2013). Under high temperature conditions, it has been reported that entire potato crop may destroy, if crop is infested with an early outbreak of Phytophthora infestans (Potato late blight) (Caubel *et al*., 2012). Fruit colour is having significant importance in assessing the marketable quality of tomato. The optimum temperature for development of lycopene pigment in tomato is 25-30°C. Degradation of lycopene starts at above 27°C and it is completely destroyed at 40°C. Similarly high temperatures above 25°C affect pollination and fruit set in tomato (Kalloo *et al*., 2001). Under high temperature in Tomato 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 (Peet *et al*., 1997). Lurie *et al*., (1996) in Tomato 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. Germination of cucumber and melon seeds is greatly suppressed at 42°C and 45°C, respectively besides germination does not occur at 42°C in watermelon, summer squash, winter squash and pumpkin seeds. The temperature fluctuations delay the ripening and reduce the sweetness in melons. Warm humid climate increases the vegetative growth and result in poor production of female flowers in cucurbitaceous vegetables like ash gourd, bottle gourd, pumpkin that causes low yield. High temperatures would cause enhanced abscission of flower buds, flowers and young pods and reduce pod production, mature pod size and seeds per pod. High temperature causes bolting in cole crops, which is not desirable as they are grown for vegetable purpose.

Damage caused due to exposure of the plant above 0°C (0°C-10°C) is chilling injury and slight exposure to less than freezing point of a plant 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 due to low temperatures. Crop plants that develop in tropics, may experience serious freezing injury, even by 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 its 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. 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). Seeds are especially (beans) sensitive to low temperatures during imbibitions and may not germinate at low temperatures.

<u>Drought:</u> Uneven distribution and failed monsoon are among the major events behind the drought like situation. The 21.06 per cent area is under different degrees of drought ranging from abnormally dry to exceptionally dry. While 1.63 per cent area and 1.73 per cent land is under 'extreme dry' and 'exceptional dry' conditions, 2.17 per cent is under 'severe' dry conditions. As much as 8.15 per cent is under 'moderate' dry conditions according to recent data released by Drought Early Warning System (DEWS), a real-time drought-monitoring platform. Around 7.38 per cent land is 'abnormally' dry, according to the latest record released August 16, 2021. 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. The prevalence of drought conditions adversely affects the germination of seeds in vegetable crops like onion and okra and sprouting of tubers in potato, also induces flower abscission in tomato. Potato is highly sensitive to drought, even 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. Chilli also suffers drought stress, leading to yield loss up to 50-60%. Vegetables, being succulent, consist of greater than 90% water. Thus, water greatly affects the yield and quality of vegetables; drought conditions reduce vegetable productivity drastically. Drought stress causes an increase of solute concentration in the environment (soil), leading to an osmotic flow of water out of plant cells. This leads to an increase of the solute concentration in plant cells, thereby reducing 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 on vegetables. The pervasiveness 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). 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. 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 (D Pena *et al., 2007*. The movement of solutes like proline, carnitine, sucrose, polyols and fructans, which are precursors of the nutritional compounds in vegetables are translocated to other parts of the plant which hinders the formation of in the vegetables and thereby affecting the nutritional compounds in vegetables. Also, the movement of elements from the roots is hindered due to drought stress which affects the nutrients in vegetables (Hoekstra *et al*, 2001). Kumar et al., 2021 reported that the reduction in marketable tuber yield was found not only due to smaller tuber size formation but also because water stress increased the formation of deformed tubers like knobby, dumbbell shaped and cracked tubers. Indira *et al.,* 2004, concluded that drought stress significantly reduced nitrogenous compounds and root yield. Root dry matter by contrast increased as water stress increased and was the most sensitive root quality trait. It therefore served as the best indicator and selection criterion for drought resistance.

Salinity: Around 6.74 million ha area in the country is salt-affected. Estimates suggest that every year nearly 10% additional area is getting salinized, and by 2050, around 50% of the arable land would be salt-affected. According to an estimate, worldwide 20% of total cultivated and 33% of irrigated agricultural lands are afflicted by high salinity (Shrivasata and Kumar, 2015). Global economic losses due to soil salinization are around US $ 27.3 billion per year (Qadir *et al*., 2015).

Low precipitation, high surface evaporation, weathering of native rocks, irrigation with saline water, and poor cultural practices are the major factors contributing to the increasing soil salinity. Visual symptoms of salt injury in plant growth appear progressively. Generally, the first signs of salt stress are wilting, yellowed leaves, and stunted growth. In a second phase the damage manifests as chlorosis of green parts, leaf tip burning, and necrosis of leaves, and the oldest leaves display scorching. Salt accumulation in the root zone led to the development of osmotic stress and disrupts cell ion homeostasis by inducing both the inhibition in uptake of essential elements such as K^+, Ca^{2+}, and NO^{3-} and the accumulation of Na^+ and Cl^-. Specific ion toxicities are due to the accumulation of sodium, chloride, and/or boron in the tissue of transpiring leaves to damaging levels. Accumulation of injurious ions may inhibit photosynthesis and protein synthesis, inactivate enzymes, and damage chloroplasts and other organelles. During dry conditions, considerable water loss occurs due to high evapotranspiration rate and accumulation of salt around root zone that restricts the uptake of water and nutrient by the plants. High salinity in soil alters the K+ /Na+ ratios result in ion-specific stresses that make Na+ and Cl concentrations which is harmful to plants. It affects the plants in various mechanisms like decrease photosynthesis, loss of turgidity, tissue necrosis, leaf curling, leaf abscission, wilting and even death of plant under severe conditions. The excess salinity in soil affects the ontogeny of plants and ultimately decreases the productivity of vegetables. Vegetable productivity may also get affected by the quality of irrigation water as the ground water is contaminated due to deposition of salts in bedrocks or by various natural or manmade actions. Saline soil reduces the intercellular spaces and enhances stomatal density in spinach and pea leaves, respectively. In almost all the cucurbits, high salt in soil causes reduction in total chlorophyll content, relative water content along with fresh and dry weight (Baysal *et al*., 2004). Yield of vegetables like tomato, pepper, celery, peas etc. are also badly affects by the saline soils (Maggio *et al*., 2004; Maksimovic *et al*., 2008). 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). Salt stress causes suppression of growth and photosynthesis activity and changes in stomata conductivity, number and size in bean plants. It reduces transpiration and the cell water potential in salt-effected bean plants (Kaymakanov *et al*., 2008). Mujahid *et al* 20015 concluded in their research where at 3 leaf stage four salinity levels (1.5, 3, 4.5, and 6 dS·m−1 NaCl) and six cultivars namely (Crimson, Charleston Gray, Anarkali, Chairman, Sugar Baby and Champion) tested for screening and results compared with control (non-saline). Hoagland's solution was used as nutrient medium that all morphological attributes and ionic contents were severely affected. But it was revealed by statistical analysis that Charleston Gray was affected least while Champion was most salt sensitive cultivar due to oxidative stress and ionic toxicity. It is concluded that different genotypes under consideration vary in their ability to tolerate salt stress.

Flooding: India has suffered a huge crop loss on 18.176 million hectares of land, roughly 8.5 per cent of the total gross cropped area due to floods from 2017-2019, according to data shared by the government in the Lok Sabha February 11, 2021. Of this, 10.68 mha was affected in 2019 alone. In 2018 and 2017, 2.515 mha and 4.973 mha of cropped area was lost in India. Waterlogging, or flooding of soil, can cause considerable injury, reduced growth rate, and even death in crop plants. The lack of oxygen in the root zone and uptake of nutrients is the major cause of limited plant growth in waterlogged soils. Flooding also causes adverse changes in the hormone content of the plant. Thus, flooding is a problem of considerable economic importance in many parts of the world. In addition, waterlogging increases susceptibility of plants to disease organisms, particularly root rotting fungi. These changes adversely affect the growth and development of plants resulting in poor quality and reduced yield. Micronutrients (boron, chlorine, copper, iron, manganese, molybdenum and zinc) are vital for plant growth and play a significant role in quantity and quality production of vegetable crops. In Flooding, nutrients leach and washes out from upper fertile soils together with erosion of soils may results in nutrient deficit soils that directly affect the productivity of vegetables. In a flooded soil, there occurs shortages of O_2 and an increase of carbon dioxide (CO_2) in the root system, by interfering with water uptake, induces a temporary depression in conductivity across the membranes, which in turn may cause leaf dehydration (Bradford and Yang, 1981). Soil deficient in any one of the micronutrients can diminishes the production even all the nutrient available. The decomposition rates of organic sources may also hamper due to rapid loss of chemical nutrients by soil biology. Chilli plants sensitive to waterlogged condition, which decreases oxygen supply and nitrogen uptake by roots causes yellowing of leaves, suppresses growth, blackening of roots and swelling at root shoot junction (Hasnain and Sheik, 1976). Tomato, pepper, onion, potato, melons, pea and beans etc. are highly sensitive to waterlogged condition. It is also reported that water logging coupled with high temperature in tomato cultivation results in wilting and eventually death of plants (Kuo *et al*., 1982). Under flooded condition, roots respiration gets hampered because soil air replaced by water resulting in improper nutrient uptake and also leads prone to soil borne diseases. Survivality and growth of asparagus is reduced, if transplants are placed under submerged condition for 3-4 weeks (Falloon *et al*., 1991). Pepper (Capsicum annum) 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 and Sheik, 1976) caused by decreased O_2 supply, decreased N uptake by roots, and development of cortical cells. Also, 24-h flooding periods at 7, 17, and 27 d after transplanting increased the mortality of pepper plants infested with Phytophthora capsica by 20%, 53%, and 100%, respectively (Bowers and Mitchell, 1990). This was attributed to increased zoospore release associated with high soil moisture. Tomato plants affected in waterlogged condition because oxygen level reduces around root zone which accrue and increases endogenous ethylene (Drew, 1979). In pea, concentration of abscisic acid increases in roots during flooding and accumulation of leaves promotes partial closure of stomata. Severe flooding causes rotting of roots, shrinkage of roots in storage and necrotic spots in leaves of sweet potato and yam (Thompson *et al*., 1992]. Flooding asparagus (Asparagus officinalis) plants continuously for 48 h after 2 and 3 weeks after trans-planting delayed growth and reduced survival of the transplanted seedlings when compared to two 8-h flooding separated by a 16-h period of drainage (Falloon *et al*., 1991).

Soil erosion, storm, wind, hail damage, volcanic eruption and tsunami: Each year soil erosion and other forms of land degradations rob the world of 5-7 million hectares of farming land. It is estimated that 1/6th of global soils has already been degraded by erosion due to water and wind, resulting in a reduced ability to produce sufficient food (agriculture) (COST, 2008). During the 1990s, Asia experienced 332 that is 40 per cent, of 821 windstorms reported globally, according to the World Disaster Report of the International Federation of the Red Cross, 2000. Erosion of soil from the root zone causes lodging of plants which is more harmful to most of the vegetables (tomato, eggplant, 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 harmful which increases disease incidence, particularly bacterial diseases (Gordon Johnson 2013). Fruit bruising or wounding often causes the most severe losses in vegetables 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.

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 and growth and developmental stages of vegetables. 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).

Tsunamis are natural disasters and its occurrence cause floods in 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). In the case of hail, the bean plant is considered dead if it is in the cotyledon stage and is cut off below the cotyledons, or if the cotyledon is damaged by hail to such a degree that they have no green leaf tissue or re-growth. The reason is that nutrients and food reserves in the cotyledons supply the needs of the young plant during emergence and for about seven to 10 days after emergence, or until there is one fully-developed trifoliate leaf. Cotyledons are the first photosynthetic organs of the bean seedling and are also major contributors for seedling growth. This makes beans particularly susceptible to damage from hail, or anything that cuts the plant off below the cotyledons early in its life. Stand reductions are likely to follow hailstorms. If the first trifoliate leaf is formed, photosynthesis by the developing leaves is adequate for the plant to sustain itself. Air pollutants (NO_2, CO_2, CH_4 etc.) cause oxidative damage to photosynthetic activity in most of the vegetables thus drastically affect yield and quality. Air pollutants such as SO_2, O_3, acid rain etc. affect the plant tissue and pathogens directly. Plants show varied response to foliar pathogens under polluted air. In addition, root attacking pathogens, such as plant nematodes may also be influenced due to host mediated effects of pollutants. Higher concentrations of SO_2 and O_3 (200-300 ppb) inhibited the germination, invasion and sporulation of plant pathogenic fungi, consequently plants developed diseases of lower severity growing in the stressed areas. Air pollutants at lower concentrations such as 50-100 ppb may act as predisposing agent and aggravate plant diseases. SO_2 and O_3 at 50-100 ppb increased the severity of fungal and nematode diseases by stimulating spore germination and invasion of fungi and egg hatching, penetration and reproduction of plant parasitic nematodes (Khan, 2012).

High humidity because of high precipitation favors some insects like Tomato and legume pod borer (*Helicoverpa armigera*) and okra and eggplant leaf hopper (*Amrasca biguttula biguttula*). However, high humidity also favors the fungal pathogens of insects. High precipitation and humid conditions obviously favor the development and survival of pathogens there by enhances disease severity. Risk of pathogen infestations will increase with host plants having high leaf wetness or having high canopy moisture content. Due to increased anthropogenic activities, concentration of greenhouse gases like CO_2 and CH_4 is increasing in the atmosphere day by day. They are not only responsible for global warming but also cause their own direct effect on growth and development of vegetable crops. During the early season, soybeans grown in elevated CO_2 atmosphere had 57% more damage from insects than those grown in today's atmosphere and required an insecticide treatment in order to continue the experiment. It is thought that measured increases in the levels of simple sugars in the soybean leaves may have stimulated the additional insect feeding (Hamilton *et al*., 2005). 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). Relative humidity and CO_2 can potentially affect pest and disease occurrence, insects feed more on leaves with lower nitrogen content in order to get more nitrogen for their metabolism (Hunter, 2001). As Carbon dioxide is the major limiting factor for photosynthesis, Enhanced photosynthesis increase the yield of C3 crops (Potato, Carrot, Beans), but not of the C4 crops (Cabbage, Cauliflower, Turnip, Broccoli) (Cline, 2008). The ever-increasing concentration of the harmful gases like dioxides of nitrogen and sulfur in the atmosphere causes the degradation of ozone layer leading to the penetration of harmful UV rays on to the Earth surface. Vegetables like tomato, cabbage, potatoes and sugar beets are more susceptible to UV radiation than others (Pena and Huges, 2007). Exposure to higher level of UV-B significantly reduces dry weight, leaf area and plant height moreover, it inhibits tomato growth through reducing the photosynthetic area (Hao *et al*., 1997). Ultraviolet-B (UV-B) radiation negatively affects plant cell functions. Being a highly sensitive plant to UV rays, cucumber cotyledons at early stages of germination are at real risk of exposure to elevated UV radiation (Zajac and Kubis, 2010). Exposure of leaves of french bean to ultra-violet light produces external effects such as glazing and bronzing and increases susceptibility to virus infection (Benda, 1955).

Management and mitigation strategies for adapting to climate change

Cultural management practices: Use of recommended production systems according to the type of crop for improved water-use efficiency and to adapt to the hot and dry conditions. 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. Altering fertilizer application to enhance nutrient availability and use of soil amendments to improve soil fertility and enhance nutrient uptake by the crops. Providing irrigation during critical stages of the crop growth and conservation of soil moisture reserves are the most important interferences. Use of Drip Irrigation minimizes water losses due to run-off and deep percolation and water savings of 50- 80% are achieved when compared to most traditional surface irrigation methods. Water harvesting for dry land is a traditional water management technology to ease future water scarcity in many arid and semi-arid regions of the world. Rainwater and flood water harvesting have the potential to increase the productivity of arable land by increasing the yields and reducing the risk of crop failure under climate change situation.

The crop management practices like mulching with crop residues and plastic, growing crops on raised beds will increase the yield due to improved drainage that reduced anoxic stress to the root system. The production of vegetables could be taken up using clear plastic rain shelters, which can reduce the direct impact on developing fruits and also reduce the field water logging during rainy season. During rainy season planting of vegetables on raised beds is also beneficial. Protected structures can play important role to minimize the impact of temperature fluctuation, over/under precipitation, fluctuating sun shine hour and infestation of disease and pest. Farmers are progressively adopting different protected structures to combat the climatic quirks and emerging challenges in vegetable production. During rainy season Poly-tunnel are the most used structure utilized for raising vegetable seedling. Seedling rising in pro-trays and crop production inside agro-shade net also gaining popularity among the farmers. Although poly-tunnel was the most adopted structure but the performance of poly-house was emerged as best structure in field condition. Farm friendly low-cost technologies like Chinese type polyhouse is a new introduction of a protected structure for commercial utilization. Apart from this, trenches are a viable option for domestic agriculture/kitchen gardens. Another low-cost technology is the low tunnels having enough potential in cold desert Ladakh region of India. In Ladakh region many vegetables valuable crops like Tomato, Brinjal, Okra do not perform well in the open conditions and those surviving produce poor yields. Capsicum cultivation during summer season seems a profitable alternative for farmers of Ladakh region, if the crop is grown under greenhouses as compared to open field conditions (Kanwar and Sharma, 2010). In cold desert of India commercial production of cucurbits is now possible through protected cultivation. Sarda melon imported in large quantity in the country can be produced in these areas easily. Production of off season (August and September) muskmelon, watermelon etc. in open fields has also become possible. An early crop of cucurbits like squash and long melon can also be taken in poly houses. Plastic low tunnels provide a cheap and better way for off- season cultivation of vegetable production. Low tunnels also offer several advantages like protection of the crop from adverse climate along with crop advancement from 20-30 days over their normal season of cultivation. Healthy and early nursery raising can be obtained under low tunnels. Technology for cucurbits production has been extended to the farming community successfully. Since vegetables contain a very high amount of water and many vegetables are eaten raw, therefore use of quality water remains a major concern. The quality and efficiency of water management govern the yield and quality of vegetable products. The optimum frequency and amount of applied water is a function of climate and weather conditions, crop species, variety, stage of growth and rooting characteristics, soil water retention capacity and texture, irrigation system and management factor. The use of organic and inorganic mulches is common in high-value vegetable production systems. These are protective coverings that help to 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 properties of soil as well. Use of plastic mulching improves the growth of many vegetables like eggplant, okra, bottle gourd, round melon, ridge gourd, and sponge gourd compared to the non-mulched controls.

Improved stress tolerance through grafting: Grafting vegetables originated in East Asia during the 20thcentury 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. Melons grafted onto hybrid squash rootstocks were more salt tolerant than the non-grafted melons. Yetisir *et al*., 2006 Grafting of eggplants was started in the 1950s, followed by grafting of cucumbers and tomatoes in the 1960s and 1970s (Edelstein 2004). 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* (Matsubara 1989). Grafted plants were also more able to tolerate low soil temperatures. *Solanum lycopersicum* x *S. habrochaites* rootstocks provide tolerance of low soil temperatures (10 ºC to 13 ºC) for their grafted tomato scions, while eggplants grafted onto *S. integrifolium x S. melongena* rootstocks grew better at lower temperatures (18o C to 21o C) than non-grafted plants (Okimura *et al*. 1986). The watermelon grafted on bottle gourd rootstock in heavy or loamy soils enhanced flooding tolerance. Cucurbits grafted on pumpkin provide drought tolerance in sandy soil (Anonyms, 2018). Mini -watermelons grafted onto a commercial rootstock PS1313 (*Cucurbita maxima* Duchesne × *Cucurbita moschata* Duchesne) have shown 60 % increase in yield when grown under irrigation stress conditions in contrast to ungrafted melon plants. (Rouphael *et al*., 2008) found that cucumber grafted on Shintoza-type rootstock (*Cucurbita maxima* Duchense × *Cucurbita moschata*) has shown low temperature resistance and copper toxicity resistance. The watermelon grafted onto saline-tolerant rootstocks increases around 81% yield under greenhouse production (Colla *et al*., 2010). Goreta *et al*., (2008) reported that watermelon cv. Fantasy grafted onto Strong Tosa rootstock (*C. maxima* Duch × *C. moschata* Duch) increases the shoot weight and leaf area even under saline conditions. Soil bore diseases like verticilium wilt, bacterial wilt, fusarium wilt, corky root etc. and nematodes area some of the biotic stresses cause damage in vegetable production especially in continuous cropping of greenhouses (Lee *et al*., 2003; Pogonyi *et al*., 2005). Pepper scion (Nokk wang) grafting onto breeding lines (PR 920, PR 991 and PR 922) resistant to Phytophthora blight and bacterial wilt showed greater rate of survival when they were inoculated with *Phytophthora capsici* and *Ralstonia solanacearum* (Jang *et al*., 2012)

Developing Climate-Resilient Vegetables: To meet the challenges of a changing climate improved, adapted vegetable germplasm is the most cost-effective option for farmers. However, most modern cultivars represent a limited sampling of available genetic variability including tolerance to environmental stresses. 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 which confer such resilience. 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. Genetic variation for salt tolerance during seed germination in tomato has been identified within cultivated and wild species. A cross between a salt-sensitive tomato line (UCT5) and a salt-tolerant *S. esculentum* accession (PI174263) showed that the ability of tomato seed to germinate rapidly under salt stress is genetically controlled with narrow-sense heritability (h2) of 0.75 (Fooland, 2011]. Salt tolerance during seed germination in tomato is controlled by genes with additive effects and could be improved by directional phenotypic selection. Illumination of mechanism of salt tolerance at different growth periods and the introgression of salinity tolerant genes into vegetables would accelerate development of varieties that are able to withstand high or variable levels of salinity compatible with different production environments. *S chilense* is adapted to desert areas of northern Chile and often found in areas where no other vegetation grows. *S. chilense* has finely divided leaves and well-developed root system and has a longer primary root and more extensive secondary root system than cultivated tomato (O'Connell *et al*. 2007). Drought tests show that *S. chilense* is five times more tolerant of wilting than cultivated tomato. *S. pennellii* has the ability to increase its water use efficiency under drought conditions unlike the cultivated *S. lycopersicum* (O'Connell *et al*. 2007). It has thick, round waxy leaves, is known to produce acyl-sugars in its trichomes, and its leaves are able to take up dew (Rick 1973).

Genomics and biotechnology: Increasing crop productivity in unfavorable environments will require advanced technologies to complement traditional methods, which are often unable to prevent yield losses due to environmental stress. Genes have been discovered and gene functions understood. This has opened the way to genetic manipulations of gene associated with tolerance to environmental stresses. Environmental stress tolerance is a complex trait and involves many genes. In response to stresses, both RNA and protein expression profiles change. The genes are involved with transcription modulation, ion transport, transpiration control and carbohydrate metabolism. 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. National and international institutes are re-tooling for plant molecular genetic research to enhance traditional plant breeding and benefit from the potential of genetic engineering to increase and sustain crop productivity (Pena & Hughes 2007). The use of molecular markers as a selection tool provides the potential for increasing the efficiency of breeding programs by reducing environmental variability, facilitating earlier selection, and reducing subsequent population sizes for field testing. Molecular markers facilitate efficient introgression of superior alleles from wild species into the breeding programs and enable the pyramiding of genes controlling quantitative traits. Thus, enhancing and accelerating the development of stress tolerant and higher yielding cultivars for farmers in developing countries. Integration of QTL analysis with gene discovery and modeling of genetic networks will facilitate a comprehensive understanding of stress tolerance, permit the development of useful and effective markers for marker-assisted selection, and identify candidate genes for genetic engineering. QTLs for drought tolerance have been identified in tomato. Martin *et al*., (2010) identified three QTLs linked to water use efficiency in *S. pennellii* based on 13C composition. Three independent yield promoting regions were identified in *S. pennellii* when grown in both wet and dry field conditions. Foolad *et al* (2011) identified four QTLs associated with seed germination drought tolerance have been identified, two of which were contributed by *S. pimpinellifolium. S. pimpinellifolium* is also commonly investigated as source of salt tolerance. Lin *et al*. (2006) identified random amplified polymorphic DNA (RAPD) markers linked to heat tolerance in AVRDC - The World Vegetable Center's tomato line CL5915. A follow-up study is currently underway at the Center to fully understand the genetic mechanism of heat tolerance of CL5915. Studies indicate that stress tolerance is quantitatively inherited and, in some cases, tolerance is dependent on the developmental stage of the plant.

Consequently, multiple genes are predicted to be involved with the expression of stress tolerance. Research on the physiology of stress tolerance has demonstrated that tolerance to a specific stress is determined by several component traits and controlled by corresponding genes. A combination of a genome-wide scan of expression, using DNA arrays, and QTL analysis could provide important information in identifying the major genes association with stress tolerance. Various abiotic stresses including salinity, chilling and oxidative stresses are the critical factors limiting the cultivation and productivity of sweet potato (*Ipomoea batatas*), a root vegetable crop. It has been observed that the increased production of glycine betaine in plant cells improves their tolerance level towards these stresses. Fan *et al*., 2012 transformed sweet potato cv. Sushu-2 with a chloroplastic *betaine aldehyde dehydrogenase* (*SoBADH*) gene from *Spinacia oleracea*, which is involved in the biosynthesis of glycine betaine. The over-expression of *SoBADH* gene in transgenic sweet potato improved tolerance towards salinity, oxidative stress and low temperature by providing protection against cell damage by maintaining cell membrane integrity, stronger photosynthetic activity, reduced ROS production and activation of ROS scavenging mechanism.

CONCLUSION

Presently, the world agriculture especially the vegetable production is passing through a difficult situation and faced with the challenge of food/nutritional security to meet the requirement for ever growing population. The succulent vegetable crops are highly sensitive to climatic conditions of heat, drought and flooding. Therefore, there is an urgent need to focus attention on studying the impacts of climate change on growth, development, yield and quality of crops. The emphasis should be made on development of production systems for improved water use efficiency adoptable to the hot and dry condition. Vegetable germplasm with tolerance to drought, high temperatures and other environmental stresses, and ability to maintain yield in marginal soils must be identified to serve as sources of these traits for both public and private vegetable breeding programmes. An effective extension strategy must be in place that includes technical, socioeconomic, and political considerations. Finally, capacity building, education, promoting scientific research towards the global climate change and its impact on agriculture are the key components of a sustainable adaptation strategy to climate change.

REFERENCE

Adebayo AA. 2010. Climate: Resource and Resistance to Agriculture. Eight inaugural lecture. Federal University of Technology Yola.

Anonymous. Annual report 2016-17 Ministry of commerce and industry, 2018

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

Ayyogari, K., Sidhya, P. and Pandit, M.K., 2014. Impact of climate change on vegetable cultivation-a review. *International Journal of Agriculture, Environment and Biotechnology*, **7**, p.145.

Bale, J.S., Masters, G.J., Hodkinson, I.D., Awmack, C., Bezemer, T.M., Brown, V.K., Butterfield, J., Buse, A., Coulson, J.C., Farrar, J. and Good, J.E., 2002. Herbivory in global climate change research: direct effects of rising temperature on insect herbivores. *Global change biology*, **8**, pp.1-16.

Battisti, D.S. and Naylor, R.L. 2009. Historical Warnings of Future Food Insecurity with Unprecedented Seasonal Heat. Science, 323, 240-244. http://dx.doi.org/10.1126/science.1164363

Baysal, G., Tipirdamaz, R. and Ekmekci, Y., 2004. Effects of salinity on some physiological parameters in three cultivars of cucumber (*Cucumis sativus*). *Prog. Cucurbit Genet. Breed. Res.*, *57*.

Benda, G.T.A. 1955. Some effects of Ultra-Violet radiation on leaves of French bean (Phaseolus vulgaris. L.). *Annals of Applied Biology*, **43**: 71–85.

Bhat, Bilal PY - 2019/06/20 SP - 1 EP - 2 T1- Erratic precipitation and anomalies in temperature in Jammu is a warning sign of climate change. VL - E ER.

Bhatta, G.D., Aggarwal, P.K. and Shrivastava, A., 2015. Livelihood diversification and climate change adaptation in Indo-Gangetic plains: implication of rainfall regimes. *Journal of Agriculture and Environment*, **16**, pp.77-94.

Bowers, J.H. and D.J. Mitchell. 1990. Effect of soil-water metric potential and periodic fl ooding on mortality of pepper caused by Phytophthora capsici. *Phytopathology*, **80**:1447–1450

Bradford, K. J. and S. F. Yang. 1981. Physiological responses of plants to waterlogging. *Hort. Science* **16**: 25–30

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

Caubel, J., Launay, M., Lannou, C. and Brisson, N., 2012. Generic response functions to simulate climate-based processes in models for the development of airborne fungal crop pathogens. *Ecological Modelling*, **242:** 92-104.

Cline, W.R. 2008. "*Global warming and agriculture*", Finance and Development, Vol. 45, pp. 23.

Colla, G., Rouphael, Y., Leonardi, C. and Bie, Z., 2010. Role of grafting in vegetable crops grown under saline conditions. *Scientia Horticulturae*, **127**, pp.147-155.

COST. (2008). Technical annex to COST Action 623: Soil erosion and global change. European cooperation in the field of scientific and technical research. Retrieved June 9, 2013 from (*http://www.soilerosion.net/cost623/annex.html*).

Cotty, P.J., and R. Jamie-Garcia. 2007. Influences of climate on aflatoxin producing fungi and aflatoxin contamination. *International Journal of Food Microbiology*, **119:** 109-115.

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.

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

Edelstein, M. 2004. Grafting vegetable-crop plants: Pros and Cons. Acta Hort., 65

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 & Environment*, **25:** pp.123-130.

Ewing, E.E. 1997. Potato. In Wien H.C. (ed.) The Physiology of Vegetable crops. CAB International, Wallingford, UK, pp. 295-344

Falloon, P.G., Greathead, A.S., Mullen, R.J., Benson, B.L. and Grogan, R.G., 1991. Individual and combined effects of flooding, Phytophthora rot, and metalaxyl on asparagus establishment. *Plant disease (USA)*.

Fan, W., Zhang, M., Zhang, H. and Zhang, P., 2012. Improved tolerance to various abiotic stresses in transgenic sweet potato (Ipomoea batatas) expressing spinach betaine aldehyde dehydrogenase. *PloS one*, **7**, p.e37344.

FAO 2004. Impact of climate change on agriculture in Asia and the Pacific. Twenty-seventh FAO Regional Conference for Asia and the Pacific. Beijing, China, 17-21 May 2004.

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

Fernandes, J.J., Carvalho, M.G., Andrade, E.C., Brommonschenkel, S.H., Fontes, E.P.B. and Zerbini, F.M., 2006. Biological and molecular properties of Tomato rugose mosaic virus (ToRMV), a new tomato-infecting begomovirus from Brazil. *Plant Pathology*, **55**, pp.513-522.

Flynn, R., Phillips, R., Ulery, A., Kochevar, R., Liess, L. and Villa, M. 2002. Chile Seed Germination as Affected by Temperature and Salinity, Report 2, New Mexico Chile Task Force, pp. 112.

Foolad, M.R. Zhang, L.P and Subbiah P 2010. Genetics of drought tolerance during seed germination in tomato: inheritance and QTL mapping. Genome 46: 536-545.

Fooland, M.R and Jones, R.A. 2011. Genetic analysis of salt tolerance during germination in Lycopersicon. *Heoretical and Applied Genetics*, **81**: 321-326

Gautam, H.R., Bhardwaj, M.L. and Kumar, R., 2013. Climate change and its impact on plant diseases. *Current Science*, pp.1685-1691.

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

Goreta, S., Bucevic-Popovic, V., Selak, G.V., Pavela-Vrancic, M. and Perica, S., 2008. Vegetative growth, superoxide dismutase activity and ion concentration of salt-stressed watermelon as influenced by rootstock. *The Journal of Agricultural Science*, **146**, pp.695-704.

Grevsen, K. and Olesen, J.E., 1994. Modelling cauliflower development from transplanting to curd initiation. *Journal of Horticultural Science*, **69**, pp.755-766.

Hamilton, J.G., O. Dermody, M. Aldea, A.R. Zangerl, A. Rogers, M.R. Berenbaum, and E. Delucia. 2005. Anthropogenic Changes in Tropospheric Composition Increase Susceptibility of Soybean to Insect Herbivory. *Environmental Entomology*, **34:**479-485.

Hanson P, Gniffke P A, Shieh J, Tan CW; 2011. Solanaceous vegetable breeding at AVRDC – The World Vegetable Center to meet the challenges of climate change in the tropics. In Proceedings of the Workshop on Crop Breeding and Management of Agricultural Environment for Coping with Climate Change (Eds D.H. Wu, M.T. Lu, T.H. Tseng, Y.T. Wang & C.L. Hsiao), 163-172.

Hao, X., B.A. Hale, and D.P. Ormrod. 1997. The effects of ultravioletB radiation and carbon dioxide on growth and photosynthesis of tomato. *Canadian Journal of Botany*, **75**:213-219.

Hasnain, S. and K.H. Sheik. 1976. Effects of flooding and drainage on the growth of Capsicum annuum. *Biologia*, **22**:89–106

Hazra, P., Samsul, H.A., Sikder, D. and Peter, K.V., 2007. Breeding tomato (Lycopersicon esculentum Mill) resistant to high temperature stress. *Int J Plant Breed*, **1**: pp.31-40.

Hoekstra, F.A., Golovina, E.A. and Buitink, J., 2001. Mechanisms of plant desiccation tolerance. *Trends in Plant Science*, **6:** pp.431-438.

Hunter, M.D. 2001. Effects of elevated atmospheric carbon dioxide on insect-plant interactions. *Agriculture and Forest Entomology*, **3**:153-159.

IPCC (Intergovermental Panel on Climate Change). IPCC/OECD/IEA 1997. Programme on national greenhouse gas inventories. Intergovernmental panel on climate change.

IPCC (Intergovernmental Panel on Climate Change). (2007). Synthesis report. In: O.R.D. Metz, P.R. Bosch, R. Dave, and L.A. Meyer (eds). Fourth Assessment Report: Climate Change 2007. Cambridge University Press, Cambridge, UK

Jang, Y., Yang, E., Cho, M., Um, Y., Ko, K. and Chun, C., 2012. Effect of grafting on growth and incidence of Phytophthora blight and bacterial wilt of pepper (*Capsicum annuum* L.). *Horticulture, Environment, and Biotechnology*, **53**: 9-19.

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.

Kalloo, G, M.K. Benarjee, and R.N. Tiwari. 2001. Tomato. p. 10-28. In Thumbraj, S and N. Singh. [eds.] Vegetables Tuber crops and Spices. Directorate of Information and Publication in Agriculture, Indian Council of Agricultural Research, New Delhi.

Kanwar, M.S., Sharma, O.C. 2010. Performance of capsicum under protected cultivation in cold arid region, *J. Hill Agricult*., **1**: 88 89.

Kaymakanova, M., N. Stoeva, and T. Mincheva. 2008. Salinity and its effects on the physiological response of bean (Phaseolus vulgaris. L.). *Journal of Central European Agriculture*, **9**:749-756

Khan, M.R. 2012. Effect of elevated levels of CO2 and other gaseous pollutants on crop productivity and plant diseases National Seminar on Sustainable Agriculture and Food Security: Challenges in Changing Climate, March 27-28, 2012 pp: 197

Kiritani, K., 1988. Effects of climate change on the insect fauna. *Meteorol. Res. Rep.*, **162:** 137-341.

Kumar, S., Kumar, D., Singh, B., Singh, Y.P., Singh, P. and Kumar, A., 2021. Effect of water stress on tuber quality (dumbel, pointed, cracks and total deformed tubers) in potato (*Solanum tuberosum* L.). *Annals of Horticulture*, **14:** .84-88.

Kumar, S., Layek, S. and Upadhyay, A., 2019. Potential impact of climate changes on quality, biotic and abiotic stresses in vegetable production-A Review. *IJCS*, **7:** 636-643.

Kumar, Sanket Layek, Santanu Upadhyay, Anamika 2019/02/04 636- 643 Potential impact of climate changes on quality, biotic and abiotic stresses in vegetable production-A Review,7

Kuo, C.G., Tsay, J.S., Chen, B.W. and Lin, P.Y., 1982. Screening for flooding tolerance in the genus Lycopersicon. *Hort Science*, **17:**76-78.

Lawande, K.E., 2010.Impact of climate change on onion and garlic production. Book chapter In: Challenges of climate change Indian Horticulture. Ed: H. P. Singh, J. P. Singh and S. S. Lal. Western Publishing House, New Delhi. pp. 100-103

Lee, J.M., Oda, M. and Janic, J., 2003. Horticultural Reviews. *Grafting of herbaceous vegetable and ornamental crops*, **28:**61-124.

Lurie, S., A. Handros, E. Fallik, and R. Shapira. 1996. Reversible inhibition of Tomato Fruit Gene Expression at High Temperature. Plant Physiology 110:1207-1214.

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. *European Journal of Agronomy*, **21:** 49-159.

Maksimovic, I., Belić, S., Putnik-Delić, M. and Gani, I., 2008. The effect of sodium concentration in the irrigation water on pea yield and composition. In *Proceedings of ECO Conference*, *2008* (pp. 231-235).

Martinez Rodriguez MM, Estan MT, Moyano E, Garcia Abellan JO, Flores FB, *et al*. 2010. The effectiveness of graiing to improve salt tolerance in tomato when an 'excluder'genotype is used as scion. Environmental and Experimental Botany 63: 392-401.

Matsubara, S. 1989. Studies on salt tolerance of vegetables-3. Salt tolerance of rootstocks. Agric Bull, Okayama Univ 73:17-25.

O'Connell M.A, Medina, A.L., Sanchez, Pena P, and Trevino MB 2007. Molecular genetics of drought resistance response in tomato and related species. In: MK Razdan and AK Mattoo, (eds) Genetic Improvement of Solanaceous Crops, Vol. 2: Tomato, Science Publishers, Enfield USA pp. 261-283.

Okimura M, Matso S, Arai K, Okitsu S. Crops Res. Stn. Jpn. 1986; 9:43-58.

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

Pathology, v.55, p.513-522, 2006

Peet, M.M., D.H. Willits, and R. Gardner. 1997. Response of ovule development and postpollen production processes in malesterile tomatoes to chronic, sub-acute high temperature stress. *Journal of Experimental Botany*, **48**:101-111.

Peña, R de la & Hughes, J 2007. Improving Vegetable Productivity in a Variable and Changing Climate AVRDC.An Open Access Journal published by ICRISAT (SAT eJournal | ejournal.icrisat.org) (4) 1pp 1-22

Pena, R., and J. Hughes. 2007. Improving Vegetable Productivity in a Variable and Changing Climate. SAT e journal **4**:1-22.

Pogonyi, A., Pék, Z., Helyes, L. and Lugasi, A., 2005. Effect of grafting on the tomato's yield, quality and main fruit components in spring forcing. *Acta Alimentaria*, **34:** pp.453-462.

Pushparani Devi, A., Moirangthem Sanju Singh, Shubhashree Priyadarshinee Das and Jhilki Kabiraj. 2017. Effect of Climate Change on Vegetable Production- A Review. Int.J.Curr.Microbiol.App.Sci. 6(10)s

Rashid, I., Romshoo, S. A., & Abdullah, T. 2017. The recent deglaciation of Kolahoi valley in Kashmir Himalaya, India in response to the changing climate. Journal of Asian Earth Sciences, 138, 38-50

Rick CM 1973. Potential genetic resources in tomato species: clues from observation in native habitats. In: Srb AM (ed) Genes, enzymes and populations, Plenum Press, New York, p. 255-269.

Risse, G., Carnillon, P., Rode, J.C. and Auge, M. bradowpensubash. 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.

Rothan, C., S. Duret, C. Chevalier, and P. Raymond. 1997. Suppression of Ripening-Associated Gene Expression in Tomato Fruits Subjected to a High CO, Concentration Plant Physiology 114:255-263

Rouphael Y, Colla G, Rea E. *Hort Science*, **43**:730-736

Rybus-Zając, M. and Kubiś, J., 2010. Effect of UV-B radiation on antioxidative enzyme activity in cucumber cotyledons. *Acta Biologica Cracoviensia s. Botanica*.

Sato, S., Peet, M.M. and Thomas, J.F., 2002. Determining critical pre-and post-anthesis periods and physiological processes in Lycopersicon esculentum Mill. Exposed to moderately elevated temperatures. *Journal of Experimental Botany*, **53:** 1187-1195.

Sekhawat, G.S. 2001. Potato. P. 320-340. In Thumbraj, S and N. Singh [eds.] Vegetables Tuber crops and Spices. Directorate of Information and Publication in Agriculture, Indian Counsil of Agricultural Research, New Delhi

Shrivasata, P., and Kumar, R. 2015. Soil salinity: a serious environmental issue and plant growth promoting bacteria as one of the tools for its alleviation. *Saudi J. Biologi. Sci.* 22, 123–131. doi: 10.1016/j.sjbs.2014.12.001

Singh, S. and Bainsla, N.K., 2015. Analysis of climate change impacts and their mitigation strategies on vegetable sector in tropical islands of Andaman and Nicobar Islands, India. *Journal of Horticulture*, pp.1-5.

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 115ham

Smith, M.R., Singh, G.M., Mozaffarian, D. and Myers, S.S., 2015. Effects of decreases of animal pollinators on human nutrition and global health: a modelling analysis. *The Lancet*, *386*(10007), pp.1964-1972.

Tesfaendrias, M.T., McDonald, M.R. and Warland, J., 2013. Long-term yield of horticultural crops in Wisconsin in relation to seasonal climate in comparison with Southern Ontario, Canada. *HortScience*, **48:** 863-869.

Thompson PG, Smittle DA, Hall MR; 1992 Relationship of sweet potato yield and quality to amount of irrigation. Hort Science, **27**:23-26.

Wichelns, D. and Qadir, M., 2015. Achieving sustainable irrigation requires effective management of salts, soil salinity, and shallow groundwater. *Agricultural Water Management*, *157*, pp.31-38.

Wurr, D.C.E., Fellows, J.R. and Hambidge, A.J., 1995. The potential impact of global warming on summer/autumn cauliflower growth in the UK. *Agricultural and forest meteorology*, **72**, pp.181-193.

Yetsir H, Caliskan Me, Soylu S, Sakar M., 2006. Some physiological and growth responses of watermelon (Citrullus lanatus (Thunb). Matsum. And Nakaij gafted onto Lagenaria siceraia to flooding Environmental and Experimental Botany, **58**:1-8.