# Vegetable Production in Changing Climate and their Mitigation Strategies-A Review

SACHITANAND DAS, DIPIKA MAL
Department of Horticulture,
School of Agriculture, Lovely Professional University, Phagwara - 144411, Punjab, INDIA.

*Abstract:*Low vegetable production worldwide is mainly the result of climate change; many major vegetables have lower average yields due to the changing weather conditions. Decreased availability of water, rising temperatures, flooding, and salinity are the biggest obstacles to increasing vegetable productivity. Vegetable production becomes unprofitable as a result of reduction in yields, crop failures, pest and disease and quality declines problems caused by changing climatic conditions. A great deal of physiological and enzymatic activity depends on temperature and they are affected by climate change. Increasing temperatures adversely affects vegetable production by causing drought and salinity. It has also been documented that pests and diseases are becoming more prevalent as a result of climate change. A climatic change mitigation strategy must be implemented for vegetable crops. Developing systems for improving water use efficiency suitable for conditions of heat and drought should be the main focus. Moisture is retained in soil by using crop residues and plastic mulches. Cultivation of vegetable crops on raised beds is a great way to overcome excessive soil moisture caused by heavy rain. To meet these challenges, breeding techniques, genetics, biotechnology, and non-conventional approaches are essentially necessary to develop genotypes resistant against moisture stress, high temperatures, salinity, and climate change. Consequently, this paper evaluates how climate change impacts the vegetables production and its management strategies.

*Key-words:* Abiotic stress; Climate change; Mitigation; Productivity; Vegetable crops

Received: July 23, 2022. Revised: April 25, 2023. Accepted: May 23, 2023. Published: July 3, 2023.

## 1. Introduction

Any plant or plant product whether they are raw or cooked can be considered as a vegetables. Fresh, edible portions of herbaceous plants are called vegetables [1]. The four major types of vegetables include fruit vegetables, root vegetables, green leafy vegetables, and bulb vegetables. Nutritionally, vegetables offer a wide range of vitamins, carbohydrates, salts, and proteins. These crops provide much higher incomes and job opportunities per hectare to small holder farmers than staple crops, since they are the best sources of micronutrients. Despite China having the highest yield (22.5 t/ha), India is the second largest vegetable producer (17.3 t/ha) [2]. There are over four million hectares of tomato fields around the globe and among all the vegetable crops, tomatoes are the major vegetable crop globally [3]. Physiological and biochemical processes are significantly affected by insufficient soil moisture and high temperatures, as vegetable crops are sensitive towards environmental extremes.

Various climatic parameters, including temperature, relative humidity, atmospheric gas composition and precipitation, can change over a longer period of time and over a larger geographical area as a results of climate change. There are a variety of climatic changes affecting the vegetable production, ranging from increasing atmospheric temperature and precipitation patterns to excessive UV radiation, droughts and floods [4]. It is crucial that sudden changes in temperature and irregular precipitation are taken into account during the various growth stages of crops, as they can influence their growth, flowering, pollination, fruit development, and ultimately their yield. Agricultural performance, including vegetable crops, is affected severely by climate changes and their variability. Additionally, reduction in supply of water, terminal heat stress and a short growing period will likely result in decreased production of fruits and vegetables. There have been greater uncertainties and risks associated with a combination of climate variability and climate change, further limiting the production of vegetables. A changing climate may lead to higher vegetable crop prices. A changing climate also promotes pathogen proliferation and disease evolution. Sustainability and competitiveness needs to be adopted in order to meet the growing demands of targeted population in the environment of climate change. A climate-smart vegetable intervention is needed that is highly location-specific and knowledge-intensive in order to improve production in a challenging climate [6, 7]. As a result, this paper aims to provide an overview of how climate change impacts the production of vegetables and its management strategies.

## 2. Changing climates and their effects on vegetable production:

There is a strong correlation between climate variability and vegetables crops. The effect of extreme environmental conditions on vegetables has been studied by Bhardwaj and therefore, climate change will further worsen low yields caused by high temperatures [3]. A key limiting factor for increasing vegetable productivity are increasing temperatures, salinity, flooding and reductions in irrigation water availability. Due to global climate change, particularly the irregular rainfall patterns and high temperature spells that are unpredictable, vegetables are expected to have lower productivity. According to Bhardwaj [3], excess water can have a dramatic impact on vegetable quality and yields; drought also reduce vegetable yields significantly, and tomatoes are among the most sensitive vegetables. Here is a list of some of the most important environmental stresses affecting vegetable crop production:

**Temperature:**

Variations in daily mean maximum and minimum temperatures are the primary effect of climate change on vegetable production. Temperature fluctuations have a significant impact on many metabolic, biochemical, and physiological activities of plants. In high temperatures, plants grow slower, develop slower, and yield less. Hazra *et al.* [9] summarized fruit set failure symptoms affected by high temperatures, including buds dropping, flower development abnormalities, pollen production problems, dehiscence and viability issues, and ovule abortions. In tomato, pollination and fruit set are negatively affected by high temperatures above 25°C [10]. Additionally, high temperatures cause flower drop, ovule abortion, and poor chilli fruit set as well as a reduction in the red colour in ripe chilli fruits [11]. A 42°C temperature will not allow to germinate the seeds of summer squash, pumpkin, watermelon and winter squash, whereas a 42°C temperature and 45°C temperature will greatly suppress the cucumber and melon seeds respectively [12]. It has been shown that humidity increases vegetative growth as well as reduces female flower production in cucurbitaceous plants, such as ash gourds, bottle gourds and pumpkins [13]. A high temperature would also lead to more abscission of leaves, buds and flowers and reduce the number of mature pods and seeds per pod, as well as reduce the production of mature pods and mature pod size. When cole crops are grown for vegetable purposes, high temperatures causes bolting [10].

**Drought:**

There will be a tremendous impact on crop productivity by severe water stress conditions due to climate change. Several plant species suffer yield losses of over 50% because of drought in semi-arid and arid areas. Plants may experience various biochemical, physiological, and genetic responses in response to drought stress when there is insufficient rainfall or adequate soil moisture [14]. Potato tubers are less likely to sprout during drought conditions and as a result of drought conditions, vegetable crops such as okra and onion are adversely affected [11]. Tomato flower abscission is induced by drought conditions [15]. Tomato yields can be reduced by more than 50% due to water stress condition during reproductive stages [16]. Vegetable productivity is reduced by drought stress because its physiological and biochemical processes are inhibited, including photosynthesis and respiration rate [17].

**Salinity:**

There are many salt-affected areas where salinity reduces crop growth and productivity. In spite of the fact that most vegetables are particularly sensitive to soil salinity, excessive soil salinity has a negative impact on many agricultural crops, including many grains and many vegetable crops. During salt stress conditions, the plant loses turgor, reduces its growth, wilts, leaves abscise, decreases its photosynthesis and respiratory rate, loses cellular integrity, develops tissue necrosis, and eventually dies [18]. Several crops, including onions, cucumbers, eggplants, peppers, and tomatoes, are moderately affected by saline soils [17]. When cabbage is exposed to salinity condition, its germination rate, germination percentage, shoot and root length as well as overall weight are reduced [19]. Almost all plant growth parameters in chilli are affected by salinity, according to Lopez *et al*. [20]. Additionally, the author concluded that salinity has a greater impact on the fruit production than individual fruit weight. Dry and fresh weights of all cucurbits decrease when salt content is high. When beans are exposed to salt stress, they lose growth and photosynthesis. A high salinity level in soil and irrigation water affects many physiological and metabolic processes.

**Flooding:**

Vegetable crops are generally considered flood-susceptible crops, which may be adversely affected by flooding as well as other abiotic stresses [21]. Vegetables are generally damaged by flooding because their roots do not receive enough oxygen, which inhibits aerobic activity. In floods, tomato plants accumulate endogenous ethylene, which damages them [22]. It has been suggested that ethylene accumulation is responsible for tomato leaves' rapid growth during waterlogged conditions [23]. When temperatures increase, flooding symptoms become more severe; tomato plants usually wilt and die rapidly after a short flood exposure at high temperatures [24]. During bulb development, onion yields can also be adversely affected by flooding, which can result in a 30-40% loss in yield. It is estimated that these stresses account for more than 50% of yield losses worldwide, and how plants respond to them is determined by their developmental stage, length and severity [25]. As a consequence, leaf water potential increases, stomatal conductance decreases, and carbon exchange rate is markedly reduced, resulting in an increase in intercellular CO2 concentration [26]. In addition to detrimental effects on physiological functioning, flooding negatively impacts the reproductive and vegetative growth of plants [27]. Waterborne pathogens can spread more easily during floods, while plants can become infected during droughts and heat waves, and spores can spread more widely during thunderstorms [28].

**Pests and diseases responses to climatic change:**

There is also a link between climate change and the ecology and biology of insect pests [29]. When temperatures are raised, certain insects with short life span, including diamondback moths and aphids, are more fertile and their life cycles are completed sooner. This means that they can produce a greater number of generations per year than they normally would [30]. Insects that live in soil for most or part of their lives suffer more from temperature changes than insects who live above it, since soil provides an insulating medium for temperature changes to be buffered more than the air [31]. Pest species may be adversely affected by higher temperatures in the tropics following the migration of insects to higher latitudes due to increased temperature. When the ambient temperature is high, insects develop faster, oviposit more, infest, and introduce invasive species [32]. Since insects are stenotherms (cold-blooded), they are sensitive to temperature. The European corn borer, Colorado potato beetle, cabbage maggots, onion maggots, and European corn borer will develop at a faster rate as the temperature rises. Airborne pathogens are more likely to survive when temperatures are higher due to reductions in frost [34]. As viral diseases appear earlier in the winter and insect vectors of viral diseases are more prevalent, potatoes and sugarbeet are more susceptible to them [33]. Increasing the average minimum temperature leads to a reduction in frost, which means it is no longer a limiting factor for *Fusarium*, among other pathogens [28].

## 3. The following practices can be used to adapt the climate change:

**Cultural management practices:**

In the dry and hot conditions, water-use efficiency needs to be improved by utilizing recommended production methods. A change in planting dates or sowing dates might be a good way to combat with water stress and high temperatures during the crop growing season, according to Welbaum [35]. The application of fertilizers needs to be modified to enhance nutrient availability, and soil amendments can be used to improve soil fertility and nutrient uptake [7, 36]. When crops are growing in critical stages, irrigation is essential to preserve soil moisture reserves [37]. In addition to crop residue mulching and plastic mulching, crop management practices will help to preserve soil moisture. The health of crops can be improved by raising them on raised beds when excessive soil moisture develops from heavy rains [38]. It has been shown that planting vegetables in raised beds during rainy season results in a higher yield because effective drainage reduced root anoxic stress [35].

**Improved stress tolerance through grafting:**

Tomato, eggplant, and cucumber production is severely affected by soil-borne diseases such as *fusarium wilt*, which has been grafted out during the 20th century in East Asia [39]. In general grafting is considered as a common method of improving environmentally-stress tolerance of vegetable and horticultural crops [40]. There are various abiotic stresses that plants may experience, so the root system of the plant can be modified by grafting in order to enhance its tolerance capacity against them [41]. Abiotic stress resistance among vegetable crops can be improved with grafted plants, which are now used in association with rootstocks that are tolerant to drought, low temperatures, flooding and salinity [40,42,43]. In recent years grafted plants have been increasingly cultivated in crops like eggplant, pepper, cucurbits and tomato [44,45]. The practice of grafting cucumbers and tomatoes began in the 1960s and 1970s, while eggplants were adopted in the 1950s. When temperature-sensitive tomato varieties are grown on heat-resistant rootstocks, they adapt better to heat stress condition [8]. Tomato plants with grafting develops better than those without grafting under heat-stress conditions. In addition, eggplant fruit yield increased by 10% when grafted on a heat-tolerant rootstock.

**Developing climate resilient vegetables:**

Utilizing improved, adapted vegetable germplasm is the most cost-effective solution to a changing climate [47]. There are a limited number of modern cultivars that can withstand environmental stresses, but most of them represent only a limited selection of genetic variability. By discovering novel genetic variation that is able to tolerate different biotic and abiotic stresses, superior varieties may be developed so that they can cope with a broader range of climatic conditions. Identifying and improving genotypes with improved attributes could be achieved by combining alleles from multiple loci. These superior genotypes and traits must be identified using improved selection techniques. Studying a plant's ability to adapt more quickly to variable environmental conditions is a powerful way to identify genes or gene combinations that confer such resilience [48]. The genetic and physiological complexity of crops has limited the success of conventional breeding programs in improving salt tolerance [49]. A breeding program for salt tolerance must account for genetic variability and the ability to transfer genes between species. Most tomato cultivars are moderately sensitive to salinity increases and display only limited variation among tomato species [50].

**Biotechnology:**

Environmental stresses often result in yield losses that cannot be prevented by traditional methods, so advanced technologies will be required to increase crop productivity in unfavorable environments. Discoveries of genes and understandings of gene functions have been made. Genes that confer tolerance to environmental stresses can now be genetically modified. Despite their potential for greater returns, these tools are expensive to use. Some successes have been achieved with the help of genetic and molecular tools. An analysis of molecular markers is not yet capable of identifying QTLs underlying stress tolerance in vegetables, but research is underway. Tomatoes have been found to have QTLs for drought tolerance. It is also common to investigate *S. pimpinellifolium* as a salt-tolerance source. Salt tolerance can be quantitatively inherited based on QTL mapping [50]. Polymorphic RAPD (random amplified polymorphic DNA) markers were found in CL5915, a tomato line developed by AVRDC-The World Vegetable Center. CL5915's genetic mechanism of heat tolerance is currently being investigated at the Center. A plant's tolerance to stress can differ depending on the stage of its development, since stress tolerance is quantitatively inherited.

**Prospects of Work:**

An agro-ecological region and individual crops must be considered when developing crop-based adaptation strategies for sustaining productivity. There is a lack of systematic knowledge concerning how climate change affects vegetable crops and how to develop adaptation measures. In order to overcome the challenges posed by climate change by innovative research and find solutions, it is urgent to discuss how climate change will affect vegetable crop growth, development, and quality at this moment. Adaptation strategies, mitigation technologies, and policy issues could be updated as follows:

- The importance of education, research, and development should be prioritized in order to enhance the ability of vegetable crops to adapt to climate change.
- An action plan that addresses both short- and long-term issues is essential for mitigating climate changes' impact on vegetables.
- Identifying and developing varieties of vegetables that can withstand stress.
- In order to solve the drought conditions, pond water can be collected and judiciously utilized through drips, mists, and sprinklers along with soil moisture conservation practices such as mulching.
- It is possible to increase the yield and growth of crops by grafting a scion onto a root stock that can withstand drought, heat, and salt stress.
- To reduce the effect of climate change, growers need education and awareness programmes, modifications to their current methods, and a greater use of greenhouse technologies.

## 4. Conclusion

The world's agriculture, especially vegetable production, is facing difficulties in meeting the rising demand for food and nutrition. As the population continues to grow, we must produce more and more food on a smaller piece of land in order to feed everyone. Changes in climate occur continuously. We can only take further mitigation steps if we better understand the impacts of climate change. Human intervention as well as natural environmental factors adversely affect climate sensitivity. Researchers found that environmental aberrations caused by anthropogens, such as floods, droughts, salinity, high temperatures, etc., along with pest and disease scenarios, shifted cropping seasons, growth and yield patterns and insect pollinating behaviours were most responsible for climate change. The production of vegetables is reduced by increasing temperatures, which results in a decrease in economic yield. It is impossible to eliminate all the effects of climate change, but through sincere intervention it can be minimized. It is necessary to develop effective adaptation strategies for vegetable crops to mitigate the adverse effects of climate change. It is important to develop production systems that are suitable for hot and dry conditions in order to improve water utilization. Using crop residues and plastic mulches as crop management practices can help conserve soil moisture. Crops can be grown on raised beds to overcome soil moisture problems caused by heavy rains. Last but not least, sustainable adaptation to climate change relies greatly on building capacity and educating the public.

**Conflict of Interest:** The authors declare no competing interest whatsoever.

**Authors' Contribution Statements:** The authors claim that they contributed equally to the article.

**Acknowledgment:** The authors appreciate the help of all those who helped in the course of doing this review, through one way or the other.

*References*

[1]. Ward AW (2016). Encyclopedia britannica.

[2]. Kumar B, Mistry NC, Chander BS, Gandhi P (2011). Indian horticulture production at a glance. Indian horticulture database 2011. National horticulture Board, Ministry of Agriculture, Government of India.

[3]. Bhardwaj, M. L. (2012). Effect of climate change on vegetable production in India. *Vegetable Production under Changing Climate Scenario*, 1-12.

[4]. Tirado, M. C., Clarke, R., Jaykus, L. A., McQuatters-Gollop, A., & Frank, J. M. (2010). Climate change and food safety: A review. *Food Research International*, *43*(7), 1745-1765.

[5]. Afroza, B., Wani, K. P., Khan, S. H., Jabeen, N., Hussain, K., Mufti, S., & Amin, A. (2010). Various technological interventions to meet vegetable production challenges in view of climatic change. *Asian journal of Horticulture*, *5*(2), 523-529.

[6]. Malhotra, S. K., & Srivastva, A. K. (2014). Climate smart horticulture for addressing food, nutritional security and climate challenges. *Shodh Chintan-Scientific articles,by Srivastava AK et al., ASM Foundation, New Delhi, pp83-97*.

[7]. Malhotra, S. K., & Srivastava, A. K. (2015). Fertilizer requirement of Indian horticulture An analysis. *Indian Journal of Fertilizer*, *11*(7), 16-25.

[8]. Abdelmageed, A. H., Gruda, N., & Geyer, B. (2004). Effects of temperature and grafting on the growth and development of tomato plants under controlled conditions. *Rural Poverty Reduction through Research for Development and Transformation (2004 oct. 5-7: Berlin)*.

[9]. Hazra, P., Samsul, H. A., Sikder, D., & Peter, K. V. (2007). Breeding tomato (*Lycopersicon esculentum* Mill) resistant to high temperature stress. *International Journal of Plant Breeding*, *1*(1), 31-40.

[10]. Thamburaj, S., & Singh, N. (2001). *Textbook of vegetables, tubercrops and spices*. Indian Council of Agricultural Research.

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

[12]. Kurtar, E. S. (2010). Modelling the effect of temperature on seed germination in some cucurbits. *African Journal of Biotechnology*, *9*(9).

[13]. Ayyogari, K., Sidhya, P., & Pandit, M. K. (2014). Impact of climate change on vegetable cultivation a review. *International Journal of Agriculture, Environment and Biotechnology*, *7*(1), 145.

[14]. Vadez, V., Berger, J. D., Warkentin, T., Asseng, S., Ratnakumar, P., Rao, K., & Zaman, M. A. (2012). Adaptation of grain legumes to climate change: a review. *Agronomy for Sustainable Development*, *32*(1), 31-44.

[15]. Bhatt, R. M., Srinivasa Rao, N. K., Upreti, K. K., & Jyothi Lakshmi, M. (2009). Hormonal activity in tomato flowers in relation to their abscission under water stress. *Indian Journal of Horticulture*, *66*(4), 492-495.

[16]. Srinivasa Rao NK, Bhatt RM (2012). Responses of tomato to moisture stress: Plant water balance and yield. *Plant Physiology and Biochemistry*, New Delhi. 19: 33-36.

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

[18]. Cheeseman JM (2008) Mechanisms of salinity tolerance in plants. *Plant Physiology*, 87: 547-550.

[19]. Jamil, M., & Rha, E. S. (2004). The effect of salinity (NaCl) on the germination and seedling of sugar beet *(Beta vulgaris* L.) and cabbage (*Brassica oleracea* L.). *Plant resources*, *7*(3), 226-232.

[20]. López, M. A. H., Ulery, A. L., Samani, Z., Picchioni, G., & Flynn, R. P. (2011). Response of chile pepper (*Capsicum annuum* L.) to salt stress and organic and inorganic nitrogen sources: I. growth and yield. *Tropical and Subtropical Agroecosystems*, *14*(1), 137-147.

[21]. Parent, C., Capelli, N., Berger, A., Crèvecoeur, M., & Dat, J. F. (2008). An overview of plant responses to soil waterlogging. *Plant stress*, *2*(1), 20-27.

[22]. Drew, M. C. (1979). Plant responses to anaerobic conditions in soil and solution culture. *Commentaries in plant science*, *2*, 209-223.

[23]. Kawase M (2011) Anatomical and morphological adaptation of plants to waterlogging. *Hort Sci*, 16: 30-34.

[24]. Kuo DG, Tsay JS, Chen BW, Lin PY (2014) Screening for flooding tolerance in the genus *Lycopersicon*. *Hort Sci,* 17: 76-78.

[25]. Kumar, S. N. (2017). Climate change and its impacts on food and nutritional security in India. *Agriculture under Climate Change: Threats, Strategies and Policies*, *48*.

[26]. Liao, C. T., & Lin, C. H. (1994). Effect of flooding stress on photosynthetic activities of *Momordica charantia*. *Plant physiology and biochemistry (Paris)*, *32*(4), 479 485.

[27]. Gibbs, J., & Greenway, H. (2003). Mechanisms of anoxia tolerance in plants. I. Growth, survival and anaerobic catabolism. *Functional Plant Biology*, *30*(1), 1-47.

[28]. Pautasso, M., Döring, T. F., Garbelotto, M., Pellis, L., & Jeger, M. J. (2012). Impacts of climate change on plant diseases opinions and trends. *European Journal of Plant Pathology*, *133*(1), 295-313.

[29]. Jat, M. K., & Tetarwal, A. S. (2012). Effect of changing climate on the insect pest population national seminar on sustainable agriculture and food security: challenges in changing climate. *Indian Horticul*, *3*, 41-49.

[30]. FAO (2009) Global agriculture towards 2050 Issues Brief. High level expert forum. Rome, pp: 12-13.

[31]. Bale, J. S., Masters, G. J., Hodkinson, I. D., Awmack, C., Bezemer, T. M., Brown, V. K., … & Whittaker, J. B. (2002). Herbivory in global climate change research: direct effects of rising temperature on insect herbivores. *Global change biology*, *8*(1), 1-16.

[32]. Das, D. K., Singh, J., & Vennila, S. (2011). Emerging crop pest scenario under the impact of climate change–a brief review. *Journal of Agricultural Physics*, *11*, 13-20.

[33]. Newton, A. C., Johnson, S. N., & Gregory, P. J. (2011). Implications of climate change for diseases, crop yields and food security. *Euphytica*, *179*(1), 3-18.

[34]. Boonekamp, P. M. (2012). Are plant diseases too much ignored in the climate change debate? *European Journal of Plant Pathology*, *133*(1), 291-294.

[35]. Welbaum GE (2015) Vegetable production and practices. CABI, p: 476.

[36]. Srivastava, A. K., Das, S. N., Malhotra, S. K., & Majumdar, K. (2014). SSNM-based rationale of fertilizer use in perennial crops: A review. *Indian J. Agric. Sci*, *84*(1), 3-17.

[37]. Malhotra, S. K. (2016). Recent advances in seed spices research–a review. *Annals of Plant and Soil Research*, *18*(4), 300-308.

[38]. La Pena RD, Hughes J (2007) Improving vegetable productivity in a variable and changing climate. ICRISAT 4: 1-22.

[39]. Davis, A. R., Perkins-Veazie, P., Sakata, Y., Lopez-Galarza, S., Maroto, J. V., Lee, S. G... & Lee, J. M. (2008). Cucurbit grafting. *Critical reviews in plant Sciences*, *27*(1), 50-74.

[40]. Martinez-Rodriguez, M. M., Estañ, M. T., Moyano, E., Garcia-Abellan, J. O., Flores, F. B., Campos, J. F., & Bolarín, M. C. (2008). The effectiveness of grafting to improve salt tolerance in tomato when an 'excluder'genotype is used as scion. *Environmental and Experimental Botany*, *63*(1-3), 392-401.

[41]. Bhatt, R. M., Rao, N. K. S., & Harish, D. M. (2013). Significance of grafting in improving tolerance to abiotic stresses in vegetable crops under climate change scenario. In *Climate-Resilient Horticulture: Adaptation and Mitigation Strategies* (pp. 159-175). Springer, India.

[42]. Venema, J. H., Dijk, B. E., Bax, J. M., van Hasselt, P. R., & Elzenga, J. T. M. (2008). Grafting tomato (*Solanum lycopersicum*) onto the rootstock of a high-altitude accession of *Solanum habrochaites* improves suboptimal temperature tolerance. *Environmental and Experimental Botany*, *63*(1-3), 359-367.

[43]. He, Y., Zhu, Z., Yang, J., Ni, X., & Zhu, B. (2009). Grafting increases the salt tolerance of tomato by improvement of photosynthesis and enhancement of antioxidant enzymes activity. *Environmental and Experimental Botany*, *66*(2), 270-278.

[44]. Hassell, R. L., Memmott, F., & Liere, D. G. (2008). Grafting methods for watermelon production. *HortScience*, *43*(6), 1677-1679.

[45]. Lee, J. M., Kubota, C., Tsao, S. J., Bie, Z., Echevarria, P. H., Morra, L., & Oda, M. (2010). Current status of vegetable grafting: Diffusion, grafting techniques, automation. *Scientia Horticulturae*, *127*(2), 93-105.

[46]. Edelstein, M. (2004, March). Grafting vegetable-crop plants: pros and cons. In *VII International Symposium on Protected Cultivation in Mild Winter Climates: Production, Pest Management and Global Competition 659* (pp. 235-238).

[47]. Altieri, M. A., Nicholls, C. I., Henao, A., & Lana, M. A. (2015). Agroecology and the design of climate change-resilient farming systems. *Agronomy for sustainable development*, *35*(3), 869-890.

[48]. Pereira, J. S., & Chaves, M. M. (1995). Plant responses to drought under climate change in Mediterranean-type ecosystems. In *Global change and Mediterranean-type ecosystems* (pp. 140-160). Springer, New York, NY.

[49]. Flowers, T. J. (2004). Improving crop salt tolerance. *Journal of Experimental botany*, *55*(396), 307 319.

[50]. Foolad, M. R. (2004). Recent advances in genetics of salt tolerance in tomato. *Plant Cell,6 tissue and organ culture*, *76*(2), 101-119.