Climate change impact on fruit crops and mitigation through climate-smart production practices

Abstract

Climate change poses significant threats to fruit crops worldwide, affecting growth, development, and productivity. Warmer temperatures disrupt flowering patterns, reduce fruit set, and increase pollination failures, leading to lower yields and decreased fruit quality. Climate change also alters suitable production areas, chilling hours, and pest dynamics, further exacerbating the issue. To address these challenges, this study highlights the importance of implementing climate resilience strategies, such as cultivating climate-ready crops, adopting low-chill and drought-tolerant varieties, selecting suitable rootstocks, and utilizing agro-techniques like fruit bagging and mulching. Additionally, specific chemicals like chitosan and the Bordeaux mixture can help mitigate the negative impacts of climate change on fruit crops. By adopting these strategies, fruit producers can enhance crop resilience, reduce physiological disorders, and promote sustainable productivity in the face of climate change.

Introduction

Climate change denotes significant and enduring alterations in the climate's average state or variability, typically persisting for decades or longer (IPCC, 2007). These changes can be driven by natural processes, external factors, or human activities that alter the atmosphere or land use, impacting agriculture, horticulture, fisheries, and livestock, and ultimately affecting food security. While climate change itself is not inherently harmful, the resulting consequences can be profound.

- Extremes events that are difficult to predict,
- More erratic rainfall pattern and
- Unpredicted high temperature spell shall affect productivity.

Climate change has a profound impact on plant growth and productivity, with both positive and negative effects. On the one hand, elevated CO2 levels and temperatures may enhance root crop yields and shorten growth periods. However, human activities releasing greenhouse gases, such as carbon dioxide, nitrous oxide, ozone, and methane, contribute to global warming, leading to reduced horticultural crop production and severe consequences for agriculture (Singh *et al.*, 2016). Climate change has far-reaching effects on both human and natural systems, with temperature records showing a significant warming trend. The data reveals a 0.85°C increase from 1880 to 2012 and a 0.78°C rise between the 1850-1900 and 2003-2012 periods (Krishnan *et al.*, 2020). The rise in global average temperatures due to greenhouse gas emissions poses challenges such as:

- High temperature stress during critical crop growth stages,

- Intermittent and/or terminal drought,
- Excess moisture stresses caused by extreme rainfall events,
- Incidence of insect pest and diseases and emergence of new insect pests and diseases.

Rising temperatures can lead to water stress in crops due to enhanced evapotranspiration, resulting in increased water requirements. Furthermore, changes in seasonal temperature patterns can cause shifts in suitable growing regions for various horticultural crops, potentially creating new areas for cultivation. Overall, climate change will have a profound impact on the productivity, production, and quality of horticultural crops (Deepa and Shiyani, 2013).

India's diverse soil and climate support a wide range of horticultural crops, making it an ideal location for growing various fruits, vegetables, root and tuber crops, flowers, medicinal and aromatic plants, spices, condiments, plantation crops, and mushrooms. These crops collectively cover around 11.6 million hectares, accounting for 8% of India's cropped area, and produce approximately 91 million tonnes annually. Despite their relatively small land allocation, horticultural crops contribute significantly to India's agricultural GDP, around 30%. Additionally, the export of medicinal plants, fruits, and vegetables has shown a growing trend. Horticulture plays a vital role in India's economy, particularly in rural areas, where it generates employment opportunities and enhances income for local populations due to its labor-intensive nature (Mukherjee, 1953).

Climate change in India

India, ranked fourth among the countries most affected by climate change in 2015, is experiencing profound consequences of this global phenomenon. As a country of immense importance to the global community, it is crucial to recognize that disruptions within any part of India's land system can have far-reaching implications for the entire ecosystem. With a vast population and remarkable biodiversity, India must remain vigilant in the face of climate change. The evident and concerning effects of climate change in India further underscore the need for proactive measures and heightened awareness (Mukherjee, 1953).

Over the past century, from 1901 to 2018, the average temperature has risen by 0.7 degrees Celsius (Krishnan *et al.*, 2020). Looking ahead, projections suggest a potentially alarming increase of approximately 4.4 degrees Celsius in average temperature by the end of the twenty-first century.

Influence of temperature

Elevated temperatures can have deleterious effects on pollination, leading to increased instances of flower abortion and fruit drop. Extreme temperatures can cause delays in fruit maturation, diminish fruit quality, and hinder proper color development in fruits.

Mango trees, for instance, can tolerate temperatures up to 48 °C for short durations but have limited tolerance to cold temperatures (Mukherjee, 1953). Low temperatures can lead to flower bud initiation withdrawal in many plants, resulting in earlier dormancy breaking (Kumar and Kumar, 2007). Mango trees exhibit a propensity for vegetative growth, and increasing temperatures can lead to more leaf production, affecting flowering phenology. Interestingly, panicles emerging later in the season showed a higher percentage of hermaphrodite flowers, coinciding with periods of extreme temperatures (Balogoun*et al.*, 2016).

Environmental factors such as light intensity, light quality, temperature, humidity, and other conditions can influence the nutritional content, physical attributes, and biochemical parameters of fruits like dragon fruit (Parmar and Karetha, 2020; Parmar and Karetha, 2021). Dry root rot has emerged as a significant global concern, particularly in conditions of stress and climate change, posing a serious threat to citrus crops worldwide (Said *et al*., 2022).

Influence of irrigation water

By 2025, it is projected that a significant portion of irrigated regions in India will face increased water demands. Moreover, global net irrigation requirements are expected to rise by approximately 3.5-5% by 2025 and 6-8% by 2075, relative to a scenario without climate change. In the apple-growing regions of Himachal Pradesh, a study attributed approximately 80% of the decline in apple yield to irrigation water scarcity, while the remaining 20% was attributed to high evaporation rates (Singh *et al.*, 2016). Furthermore, these regions experienced a reduction in chill unit hours, which are essential for apple production.

Impact of relative humidity

Alterations in relative humidity levels may adversely impact fruit set, leading to excessive fruit drop in citrus fruits such as oranges, mandarins, and various temperate and subtropical fruit crops. Changes in humidity can affect fruit set by hindering pollen germination due to desiccation or drying of stigmatic fluid, resulting in poor pollen germination. Additionally, high relative humidity intensity has been linked to increased infestation of mango hopper and higher incidence of powdery mildew (Singh *et al.*, 2016).

Influence of rainfall

Adverse weather conditions, such as pre-monsoon showers, can have devastating effects on crops like grapes and dates, resulting in complete harvest loss. Rainfall during the flowering period can wash away pollen from the stigma of flowers, leading to poor or no fruit set. In Gujarat, mango production suffered a severe loss of 80-90% due to unseasonal rain followed by a heavy dew attack during the blossoming season, resulting in reduced fruit set, increased fruit drop, and a higher incidence of sooty mold and powdery mildew (Varu*et al.*, 2015). The correlation between production and maximum temperature reveals a strong positive correlation for banana and mango (39.55% and 39.37%, respectively), while grape shows a negative correlation (66.99%).

Influence of frost

In temperate climates, spring frosts pose a significant threat to plants, potentially damaging blossoms and impacting fruit set and development. The damage is primarily confined to plant parts near ground level, where it is coldest. Freezing can cause the inner sap-carrying tissues in young bark to shatter, and often the bark of young trees is killed.

Influence of CO_2 on fruit crops

Research suggests that certain pests, such as aphids and weevil larvae, may thrive in environments with elevated carbon dioxide (CO2) levels and changing climatic conditions. These changes also increase the risk of new pest incursions. In strawberries, studies have shown that elevated CO2 and high temperatures can lead to reduced fruit yields, with decreases of 12% and 35% observed when plants were provided with low and high nitrogen levels, respectively. Furthermore, elevated CO2 and high temperatures during flower induction can result in fewer inflorescences and reduced umbel size, contributing to reduced fruit yields (Parsana*et al.*, 2023).

Impact of pruning on different fruit crops

The yield and yield attributes and quality parameters were significantly influenced by various levels of pruning. Maximum fruit yield (2.44 t/ha), average weight of fruit (174.11 g), fruit length (6.59 cm), fruit girth (6.83 cm), maximum pulp weight (104.45 g), pulp: Seed ratio (8.18), pulp: rag ratio (1.82), minimum number of seed (25.55), weight of seed (13.42 g), maximum total sugar (22.33%), reducing sugar (18.47%), non-reducing sugar content (3.83%), ascorbic acid (21.55 mg/100g), TSS (22.31°Brix) and minimum acidity (0.25%) were noted in medium pruning at 20 cm (P3). Whereas, minimum days to flower initiation (73.41) were recorded with unpruned trees (P1) (Parsana*et al.*, 2023).

Climate resilience

Climate resilience refers to the capacity of a socio-ecological system to withstand external stresses caused by climate change while maintaining its functionality. It encompasses two crucial aspects:

1. Absorptive capacity: The system should be able to absorb and cope with the impacts of climate change without significant disruption to its functioning.

2. Adaptive capacity: The system should be capable of adapting, reorganizing, and evolving into more sustainable configurations that enhance its resilience and preparedness for future climate change impacts (F.P. Karagatiya*et al.*, 2023).

In the horticultural sector, several adaptation measures can be implemented to effectively manage climate change in the future.

Diversification in crop cultivation

To address the challenge of insufficient chilling, the development of low-chill cultivars is the most viable solution. However, breeding such cultivars poses significant challenges. To accelerate the breeding process and facilitate the development of suitable cultivars for major fruits, modern biotechnological approaches are necessary to map the genetic factors influencing chilling requirements (F.P. Karagatiya*et al.*, 2023). Additionally, the introduction and adaptation of low-chill cultivars for crops like apple, peach, pear, and plum can be implemented in specific regions, such as the lower hills and North Indian plains, enabling commercial cultivation within a reasonable time frame.

Crop improvement strategies

A. Climate-ready crop varieties

Certain fruit crops, such as Dragon fruit, Kair, Phalsa, Pummelo, Beal, Wood apple, Aonla, Karonda, barbarous cherry, and pomegranate, exhibit lower moisture demand and reduced transpiration rates, making them more resilient to temperature fluctuations. These crops demonstrate relatively stable flowering and fruiting processes, making them ideal for adaptation to changing climate conditions (Raj *et al.*, 2021). One of the most effective adaptation strategies is to change crops and varieties in response to changing climate conditions. Identifying crop varieties that can withstand biotic and abiotic stresses is crucial for climate resilience. Developing or identifying drought-tolerant varieties, such as Pomegranate hybrid Ruby, Annona hybrid ArkaSahan, and Grape rootstock Dogridge (Vitischampine), is essential. Exploring different races and bases, as well as the place of origin of fruits, can provide insights into climate tolerance. For example, testing mono embryonic type mango in landlogged climates with well-defined winters and polyembryonic type in coastal climates can help adapt to changed climate conditions.

B.Exploration of low-chill cultivars is underway for pome fruits, stone fruits, and nut fruits as a promising strategy. Developing low-chill cultivars is considered the most effective solution to overcome insufficient chilling. However, breeding these cultivars poses significant challenges. To accelerate the breeding process and develop suitable cultivars for major fruits, advanced biotechnological techniques are essential for identifying genetic factors controlling chilling requirements.

C.Researchers are working to develop new genotypes that can withstand high temperatures and elevated CO2 levels. While rising CO2 levels have negative impacts, they also boost tree productivity by improving water use efficiency, photosynthetic rates, sugar accumulation, and biomass production. Some crops benefit from these changes, such as C4 plants, which show increased photosynthesis rates compared to C3 plants at higher temperatures. However, C4 plants quickly reach CO2 saturation, whereas C3 plants continue to show increased photosynthetic rates even with significant CO2 increases (F.P. Karagatiya*et al.*, 2023).

D.Marker-assisted selection and transgenic crop development are crucial strategies for enhancing crop resilience against biotic and abiotic stressors. These approaches aim to improve genetic traits that boost climate resilience, such as yield increase, resource use efficiency, and stress tolerance. To achieve this, genetic enhancement techniques are employed, leveraging various sources of genetic variation, including natural variations in germplasm resources, induced variations through mutant resources, and genomic-assisted breeding techniques like CRISPR-Cas technology.(F.P. Karagatiya*et al.*, 2023).

E.The focus is on developing genotypes that possess resistance to heat and drought conditions. Efforts are being made to develop cultivars, varieties, and rootstocks that exhibit tolerance or resistance to the effects of climate change. Idso *et al.*, (2002) indicates that a 75% increase in atmospheric CO2 concentration has increased the number of fruit produced by the trees by 74±9%, the fresh weight of the fruit by 4 ± 2% and the vitamin C concentration of the juice of the fruit by 5±1%. However, negative effects of carbon dioxide accumulation in the atmosphere can be expected on the post-harvest quality potato - causing tuber malformation, occurrence of common scab and changes in reducing sugars contents on potatoes.

Development of agro-techniques based on cropping patterns, including cropping systems, intercropping, and alternative crops. Relocation of crops in alternative areas, e.g., shifting of apple belt in HP. Planting different varieties or crop species. Adjusting cropping season, modifying the planting date or date of sowing and off-seasonal production & marketing of horticultural crops. Using sustainable, customized or liquid fertilizer (Nano Fertilizer). Implementing new or improving existing irrigation systems like drip irrigation. Improvement in crop residue and weed management. Changes in land use management practices.

Efficient use of resources

Adopting new farm techniques, resource-conserving technologies (e.g. bagging of fruits, fertigation, etc.). The bagging of mango fruits at the marble stage with skirting bag and brown paper gave maximum fruit retention while bagging with newspaper bag gave the highest fruit weight and fruit bagged with newspaper and brown paper bags were free from spongy tissue.

Improved pest and disease management

Initiatives are underway to develop a forecasting system for insects and diseases, create a comprehensive database, and implement effective management strategies to improve pest and disease control in agricultural systems. Enhancing surveillance measures for pests and diseases is also a critical aspect of these efforts. Additionally, researching the impact of increasing climatic variability and change is essential, as it can lead to the rapid spread of pathogens and insect pests in agricultural environments.

Use of rootstock

Historically, rootstocks were primarily used for propagating selected scion cultivars in tree fruits, as they don't reproduce true-to-type from seed. Vegetative methods are necessary for propagating most temperate tree fruit cultivars, with some exceptions like morello tart cherry and plum. For centuries, horticulturists have used budding and grafting techniques to combine rootstocks with scion cultivars. Initially, rootstocks were obtained from seeds or suckers from cultivated trees, which resulted in variability in scion performance. However, this wasn't a major concern for early horticulturists focused on multiplying valuable scion selections. Today, rootstocks remain the primary method for fruit tree nurserymen to propagate scion cultivars, despite the availability of alternative strategies. (Kamboj *et al.*, 1997)

Use of anti-transparent

Anti-transparent substances like chitosan, kaolin, and liquid paraffin reduce water loss in plants by reflecting heat radiation, leading to decreased transpiration and surface temperatures. Chitosan has shown significant effects in increasing banana plant weight and yield. Antiperspirants reduce transpiration rates by decreasing stomata size and number, and strengthening them to stress. Most water absorbed by plants is lost through transpiration, impacting productivity. Foliar spraying increases growth parameters and relative water content, reducing transpiration in three ways: reducing solar energy absorption, forming transparent films, and controlling stomatal opening. Water stress significantly affects yield, but applying antiperspirants before this stage can conserve water and improve grain set, outweighing photosynthetic limitations. The three main types of antiperspirants are film-forming, stomatal regulating, and reflective compounds, which reduce water loss by decreasing solar energy absorption, forming transparent films, or controlling stomatal opening.

The three general types of anti transpirants are: (i) film forming (ii) stomatal regulating and (iii) reflective compounds.

High Density Planting (HDP)

Tropical fruits have significant potential for adaptation and climate change mitigation due to their high productivity and carbon sequestration capabilities. Well-managed high-density plantings of perennials can accumulate up to 1.5 times more biomass and soil carbon per unit area than traditional plantings. High-density planting (HDP) is already practiced in several tropical fruits like mango, guava, banana, citrus, pineapple, pomegranate, papaya, cashew, and coconut. These successful experiences can be applied to other tropical fruits like litchi and longan. For instance, mango, guava, and citrus can be planted at closer spacings (2.5m x 2.5m, 3m x 3m, and 1.8m x 1.8m, respectively) than traditional spacings (10m x 10m, 6m x 6m, and 6m x 6m). Effective canopy management and the use of dwarfing rootstocks, interstocks, and scion varieties are crucial for successful HDP. Additionally, combining canopy management with growth regulators is essential for optimal results. (Haldankar P.M. 2015)

The utilization of Geographic Information System (GIS) technology is gaining significance in agriculture, particularly in fruit crop cultivation. With GIS, we can generate climate suitability maps for specific fruit crops, enabling us to tailor cultivation to meet the unique climate requirements of each location. Furthermore, developing mathematical models for tropical fruit trees can help predict future scenarios and consequences of climate-related events like flooding, droughts, and elevated CO2 levels. Selecting resilient cultivars that can thrive in stress conditions and respond to elevated CO2 levels is crucial. Additionally, employing phonological scales or landmark stages is essential for understanding tree responses to climate change.

Conclusion

Climate change significantly affects fruit crops, impacting various aspects of their growth and development. This includes disruptions in flowering patterns, reduced fruit set, increased pollination failures, impaired color development, and higher instances of physiological disorders. Climate change also leads to changes in suitable areas for fruit production, resulting in inadequate chilling hours and affecting dormancy breaking and yield in temperate fruits like apples.

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References

Ahmed, YMA. 2014.Impact of spraying some anti-transpirants on fruiting of Williams's bananas grown under Aswan region conditions. *Stem Cell*. **5**(4):34-39.

Ali and Ibrahim. 2019. The effect of some rootstocks on physical and chemical properties of fruit growing process in anna apple cultivar. *Fresenius Environment Bulletin*.**28**(4):2855-2863.

Balogoun, I., Ahoton, E.L., Saïdou, A., Bello, O.D. and Ezin, V. 2016. Effect of climatic factors on cashew (Anacardiumoccidentale L.) productivity in Benin (West Africa). *Journal of Earth Science and Climatic Change*. **7**:329.

Bartsch, M., Bednarek, P., Vivancos, P. D., Schneider, B., von Roepenack-Lahaye, E., Foyer, C. H. and Parker, J. E. 2010. Accumulation of isochorismate derived 2, 3 dihydroxybenzoic 3-O-β-D-xyloside in Arabidopsis resistance to pathogens and aging of leaves. *Journal of Biological Chemistry*. **285**(33), 25654-25665.

Besufkad, A. and E. Woltering. 2006. Ethylene, 1-MCP and the anti-transpirant effect of active compound film forming blend. *Journal of Horticulture* 2:153.

Deepa and Shivani. 2013. Analysis of Vulnerability Indices in Various Agro-Climatic Zones of Gujarat. *Indian Journal of Agricultural Economics*. **68**(1):122-137.

Deshmukh, S., Jadhav, P., Sawant, P., Thorat, V. 2021. Climatic vulnerability, adoption of climate-resilient technologies and its socio economic-institutional agro ecological determinant. Adoption of Climate Resilient Technologies and its Socio economic Institutional-Agro ecological Determinant.

Fujita, M., Fujita, Y., Noutoshi, Y., Takahashi, F., Narusaka, Y., Yamaguchi-Shinozaki, K., and Shinozaki, K. 2006. Crosstalk between abiotic and biotic stress responses: a current view from the points of convergence in the stress signaling networks. *Current opinion in plant biology,* **9**(4), 436-442.

Ghule, V.S., Bhor, V.A., Zagade, P.M., Somkuwar, R.G. 2019. Effect of rootstocks on graft success, growth and photosynthetic activity in grape varieties (*Vitis vinifera* L.). *Journal of Pharmacognosy and Phytochemistry*.**8**(2):850-853.

Grobkinsky, D. K., van der Graaff, E., &Roitsch, T. 2016. Regulation of abiotic and biotic stress responses by plant hormones. *Plant Pathogen Resistance Biotechnology*, 131.

Haldankar, P.M., Parulekar, Y., Kireeti, A., Kad, M.S., Shinde, S.M., Lawande, K.E.2015. Studies on influence of bagging of fruits at marble stage on quality of mango cv. Alphonso. *Journal of Plant Studies*.**4**(2):12-20.

Hassan, F.U., Khurshid, M. Y., Ahmed, M., Akmal, M., & Afzal, O. 2015. Growth and Development of Safflower (*Carthamustinctorius*) under Rainfed Conditions.

IPCC. 2007 Climate change: Fourth assessment report of the Inter-Governmental Panel on climate change (IPCC), WMO, United Nations Environmental Programme, 2007.

Kamboj, J.S., Blake, P.S., Quinlan, J.D., Baker, D.A. 1999. Identification and quantitation by GC-MS of zeatin and zeatin riboside in xylem sap from rootstock and scion grafted apple trees. *Plant Growth Regulation*. 28:199-205

Krishnan, R., Sanjay, J., Gnanaseelan, C., Mujumdar, M., Kulkarni, A., Chakraborty, S. 2020. Assessment of Climate Change over the Indian Region. A Report of the Ministry of Earth Sciences (MoES), Government of India. P. 13-17.

Khalil, S. E., N. G. Abd El-Aziz and B. H. Abou-Leila. 2010. Effect of water stress and ascorbic acid on some morphological and biochemical composition of ocimumbasilicum plant. *Journal of American Science,* 6: 33-44.

Kumar, R., Kumar, K. 2007. Managing physiological disorders in litchi. *Indian Horticulture*. 52:22-24.

Lumba, S., Cutler, S., & McCourt, P. 2010. Plant nuclear hormone receptors: a role for small molecules in protein-protein interactions. *Annual review of cell and developmental biology*, 26, 445-469.

Mukherjee, S.K. 1953.The mango-its botany, cultivation, uses and future improvements, especially as observed in India. *Economic Botany*7:130.

Mickelbart, M. V., Hasegawa, P. M., & Bailey-Serres, J. 2015. Genetic mechanisms of abiotic stress tolerance that translate to crop yield stability. *Nature Reviews Genetics*. **16**(4), 237-251.

Mittler, R., and Blumwald, E. 2010. Genetic engineering for modern agriculture: challenges and perspectives. *Annual review of plant biology*. 61, 443-462.

Nidhi, N., Prasad, V.M., Bahadur, V. 2021. Effect of different mulching materials on growth and yield of guava (Psidium guajava L.) *The Pharma Innovation Journal.* **10**(11):1406-1409.

Parmar, V.M., Karetha, K.M. 2020. Physical and biochemical analysis of dragon fruit species from different regions of Gujarat. *Journal of Pharmacognosy and Phytochemistry*. **9**(5):2863-2866.

Parmar VM, KarethaKM. 2021. Nutritional and organoleptic evaluation of dragon fruit species from different regions of Gujarat. *The Pharma Innovation Journal.* **10**(11):3009- 3012.

Parsana, J.S., Varu, D.K., Parmar, V.M., Patel, S.,Kanzaria, D.R. and Mishra, S. 2023.Influence of pruning and integrated nutrient management on custard Apple (*Annona squamosa* L.) Agricultural Mechanization in Asia, Africa and Latin America. **54**(04):12865-12874.

Patil, N.A., Yeldhalli, R.A.,Patil, B.O., Laxmi, T.N. 2015. Impact of climate change on major fruits in India. *Asian Journal of Environmental Sciences*. **10**(1):34-38.

Prakash, M. and K. Ramachandran 2000. Effects of moisture stress and anti transpirants on leaf chlorophyll. *Journal of Agronomy and Crop Science*, 184: 153- 156.

Raj, Y., Kumar, A., Das, S., Srivatsa, V., Kumar, D., Kumar, R. 2021.A comparative analysis of compositional and phytochemical attributes in fruits of low chilling apple varieties cultivated in the eastern and western Himalaya. *Scientia Horticulturae*. 286:1-11.

Ezrari, S., Radouane, N., Tahiri, A., El-Housni, Z.,Mokrini, F., Ozer, G., 2022. Dry root rot disease, an emerging threat to citrus industry worldwide under climate change: A review. *Physiological and Molecular Plant Pathology*. 117:1-19.

Singh, N., Sharma, D.P., Hukam, C. 2016. Impact of Climate Change on apple production in India: A Review. *Current World Environment.* **11**(1):251-259.

Sorce, C., Massai, R., Piciarelli, P., Lorenzi, R. 2002. Hormonal relationships in xylem sap of grafted and ungrafted Prunus rootstocks. *Scientia Horticulture*. 93:333- 342.

Soumelidou, K., Morris, D.A., Barrely, N.H., Barnett, J.R. 1994. Auxin transport capacity in relation to the dwarfing effect of apple rootstocks. *Journal of Horticulture Sciences*. 69:719-725.

Suzuki N, Mittler R. 2006. Reactive oxygen species and temperature stresses: A delicate balance between signaling and destruction. *Physiologia Plantarum*.126:45–51.

Tripathi, P., Shah, S., Kashyap, S.D., Tripathi, A. 2019. Fruit yield and quality characteristicsof high-density *Prunus persica*(L.) Batsch plantation intercropped with medicinal and aromatic plants in the Indian Western Himalayas. *Agroforestry Systems* 93:1717-1728.

Varu, D.K., Viradia,R.R. 2015. Damage of mango flowering and fruits in Gujarat during the year, Survey report of Department of Horticulture, JAU, Junagadh.

Vasava, H.V., Tejal, M., Parasana, J.S., Varu, D.K., Patel, S., Mishra. S. 2023.Performance of different grafted varieties and mulching in brinjal (*Solanum melongena* L). Agricultural Mechanization in Asia, Africa and Latin America.**54**(04):12981-12988.

Yadollahi,A. 2011. Evaluation of reduction approaches on frost damages of grapes grown in moderate cold climate. *African Journal of Agricultural Research*. **6**(29):6289-6295.