Original Research Article

Perceptions of apple growers on Impact of Climate Change on apple production in Mid and High Hills of Himachal Pradesh

Abstract

The present study entitled "Perceptions of apple growers on Impact of Climate Change on apple production in Mid and High Hills of Himachal Pradesh" had made an attempt to analyse the perceptions of apple growers on impact of climate change on apple production. The trend analysis revealed that the productivity of apple has reduced by 11 percent from last decades, which meant that although apple growers are increasing their area under apple, but production per unit area is not increasing by much amount. there was indeed a change in climate in last decades (79.5%), as there was an increase in intensity of rainfall (77%), increase in hailstorm events (76%), snowfall events (70%), and there was also long-term changes in mean temperature (75%) and mean rainfall (75%). Due to climate change, ecological diversity had been also affected, as there was also a change in the number of insect-pests affecting apple (Increment in their population) (74%) which had also affected the productivity of apple in overall. So, it was concluded that the impact of climate change has increased in last few decades and it has negatively affected the yield of apple in our state. It has led to vegetative vigour at the cost of apple yield, reduce sugar content and elevate the fruit acids leading to tarter tasting fruits. So, there is a great need among apple growers to adapt their technologies to climate change like exploring new varieties which are high yielding and adaptable to climate change and also going for crop diversification to deal with financial losses.

Keywords: Climate change, apple, apple growers

Introduction

Apple is the commercial fruit of Himachal Pradesh on which most of our state economy depends. The state has an area of 0.12 lakh ha and production of 4.84 lakh mt of apple in 2022-23 which constitutes the 49 percent of total area under fruits and 82.5 percent of total fruit production (Economic Survey of HP, 2024). Although apple has been the significant cash crop, but it has been following a declining trend in last few years and one of the main reasons for this trend has come up as climate change. The impacts of climate change are already visible on the economies of the world through extreme weather events like droughts, floods, hailstorms, landslides, cold and heat waves, forest fires, avalanche etc. and

natural calamities like tsunami, earthquakes, volacanic eruptions etc (Singh *et al.* 2016). These climatic changes not impacted the living beings but also severely affected the agricultural production (Birthwal *et al.* 2014; Mahato, 2014). The reduction in forest cover from the past centuries due to industrial revolution has caused the soil erosion causing floods and droughts thus impacting the production of agricultural crops (Rani, 2019, Shivani *et al.* 2023). Since, stable ecosystem can help in dealing with changing climatic scenario. But climate change has emerged as a serious concern among apple growers in last few decades. The perceptions of apple growers also highlight the harmful impacts of climate change rather than other factors (Wani *et al.* 2017). The changing climatic conditions have impacted the flowering and fruit setting conditions, yield as well as the fruit quality and various ecological ramifications in horticultural crops (Kumar and Sharma, 2013; Sharma 2015). We all are well aware with the fact that apple plantations are quite sensitive to temperature, water availability, solar radiations and other climatic factors. This climatic vulnerability has caused reduction in apple production due to changes in exposure and sensitivity components which has also impacted the adaptive capacity of apple growers (Garg, 2015; Rani and Prasher, 2020). Also, impact of climate change can also manifested through various inter-connected factors like increase in pest attack and disease incidence, blossoming, fruit set, water availability and vulnerability to various seasonal changes (Sheikh and Baba, 2023).

In general, cold temperature at night and warm temperature in daytime is favourable for apple production (Awasthi *et al.* 2001). The winters must be cold enough for providing buds sufficient chilling to surpass winter rest and vegetative growth period must be longer for attaing crop maturity (Ashcroft *et al.* 1977). Reduced snowfall in winters and rainfall patterns has caused drought like conditions which has led to reduction in soil moisture which has impacted both vegetative and fruit growth in apple orchards (Chand *et al.* 2015, Rani and Prasher, 2021). Weather is a prominent factor in identifying the success rate of pollination, and flower and fruit set (Shaul, 2018). But, the fluctuating temperature conditions has caused desiccation of pollen and stigma during flowering time, and also caused poor fruit set (Jindal *et al.* 2000). Warmer temperatures has also impacted the taste and textural attributes of different apple varieties with effects on acid concentration and fruit firmness in response to earlier blooming and during maturation periods (Sugiura *et al.* 2013). Apart from this, this increase in temperature and erratic rainfall has also caused the outbreak of several weeds, diseases, and pests that has adversely affected the quality and quantity of apple fruit (Adhikari *et al.* 2023). These changing conditions has seriously affected the apple production

and to deal with changing weather conditions, apple growers has also started shifting towards growing other fruit crops like kiwi and pomegranate (Sharma *et al.* 2013).

As climatic conditions are becoming more and more vulnerable, apple growers are also facing more uncertainty in making decisions about their crop. One conclusion of this uncertainty is that apple may not have quite enough information to adequately evaluate their adaptive measures in relation to climatic risk (Sarkar and Padaria, 2010). This uncertainty can stem from social, economic, physical, relational, political and biological factors that negatively impact the knowledge needed to make effective decision-making (Adger, 1999; Charmaker and Mijar, 2009; Shankara et al. 2012). Also, effective implimentation of adaptive measures is also necessary for deal with climate change (Bryan *et al.* 2009; Venkateswarlu, 2009). So, government of our state should come up with those policy measures which are effective and useful for apple growers to adapt with changing climatic conditions. So, there is a great need to understand that how apple growers perceive climatic risks to their orchards in regions like selected in the present study *i.e.* Mandi, Kullu and Shimla which are having high area and production under apple and also are facing higher risks of climate change. Also, crop management can significantly reduce the production losses Arundhati *et al.* 2020), so, DSS (Decision Support System) is also required for efficient management of apple orchards at farm level for climate resilient crop production (Prasad, 2013). So, the present study has made an attempt to analyse the perceptions of apple growers on impact of climate change on apple production and various adaptation strategies to deal with it.

Methodology

For present study, a sample of 200 apple growers has been taken from top apple producing districts of Himachal Pradesh i.e. Shimla (70 respondents), Mandi (60 respondents) and Kullu (70 respondents) and also these districts are under higher climatic risk. For analysis, simple mathematical statistical tools like tabular analysis, percentages has been used and for significance, chi-square test has been used which has been explained below. For trend analysis, secondary data has been obtained from various government departments of Himachal Pradesh.

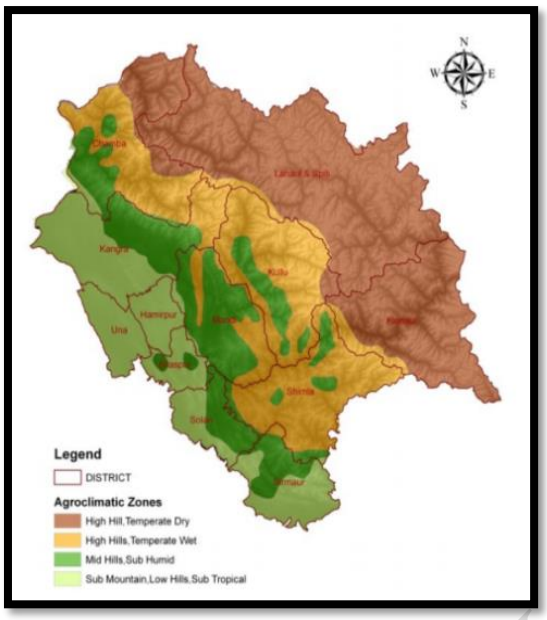

Fig 1: Different agro-climatic zones of Himachal Pradesh

Testing of apple growers' adaptive strategies to cope up with climate change using Chi square (χ^2) test

It is used to test whether the adaptive strategies taken by apple growers are significant to all the categories or to the independent category only using following hypotheses:

H_0 = Adaptive strategies have no significant difference

H_1 = Adaptive strategies have significant difference

$$\chi^2_{Cal} = \sum_{i=1}^{n} \frac{(O_i - E_i)^2}{E_i^2}$$

Where;

$O_i$is the observed value, E_i is the expected value and i = 1,2,3,……,n; where n is the number of observations. Here, we have degree of freedom equals to one as there were two categories of responses *i.e.* Yes and No. The appropriate χ^2_{Tab} is 6.635 and the decision rule is as follows: Reject H_0 if $\chi^2_{Cal} \geq 6.635$.

Results and discussion

Trend in apple productivity in last 50 years

Although area under apple has been increased in last 50 years from 0.28 lakh ha in 1971-72 to 0.12 lakh ha in 2021-22, but the production pattern has been facing declining trend from last few years. By analysis the trend in productivity of apple, it was revealed that the productivity of apple has reduced by 11 percent from last decades, which meant that although apple growers are increasing their area under apple, but production per unit area is

not increasing by much amount. The reasons behind this decline may be mostly by changing climatic scenario in the state which includes less snowfall in winter and low rainfall in summer which has created draught like conditions for apple plantations. So, it can be concluded that apple productivity has a declining trend from last few years.

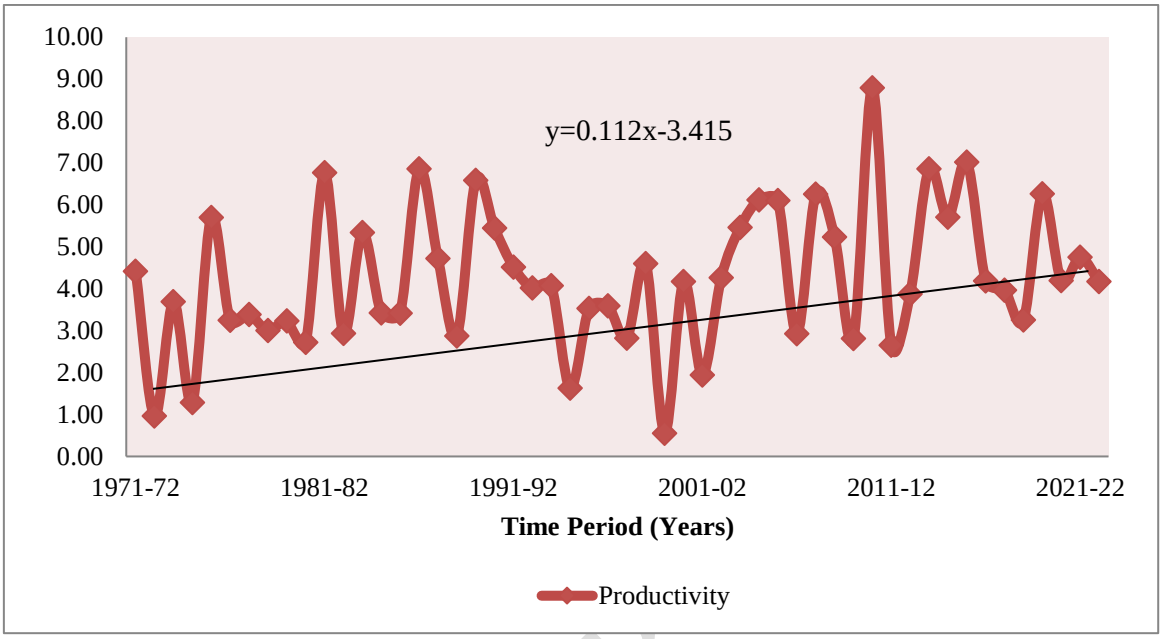

Fig 2: Trend in apple productivity from 1971-72 to 2021-22

Perceptions of apple growers towards changes in climate in recent past

It is a well-known fact that climate change has been emerged as a major concern among apple growers as there have been large variations in various weather parameters like temperature, rainfall, precipation, snowfall, hailstorms etc. which has impacted the production of apple in Himachal Pradesh. From the Table 1, it was revealed that there was indeed a change in climate in last decades (79.5%), as there was an increase in intensity of rainfall (77%), increase in hailstorm events (76%), snowfall events (70%), and there was also long-term changes in mean temperature (75%) and mean rainfall (75%). Climate change had also caused changes in timing of pre and post-monsoon (77% and 71%), which meant that climate change had indeed affected the local weather conditions of the study area.

Table 1: District-wise perceptions of apple growers towards changes in climate in recent past

(Percent)

Particulars	Mandi	Kullu	Shimla	Overall
1. Changes in climatic conditions/weather	75.00	80.00	82.86	79.50
2. Change in number of rainfall days	71.67	64.29	65.71	67.00
3. Increase in intensity of rainfall	78.33	75.71	77.14	77.00
4. Change in productivity of apple	73.33	70.00	72.86	72.00

5. Increase in hailstorm events in recent past	81.67	74.29	72.86	76.00
6. Increase in snowfall events in recent past	68.33	71.43	70.00	70.00
7. Long-term changes in the mean temperature	78.33	72.86	74.29	75.00
8. Increase in number of hot days	80.00	78.57	75.71	78.00
9. Long-term changes in the mean rainfall	81.67	72.86	71.43	75.00
10. Changes in the timing of monsoon rainfall (June-Sept)	76.67	75.71	78.57	77.00
11. Changes in the timing of post-monsoon (Oct-Dec)	75.00	70.00	68.57	71.00
12. Changes in the timing of pre-monsoon (Jan-May)	71.67	71.43	70.00	71.00

Perceptions of apple growers on various extreme induced events and other seasonal changes due to climate change

The changing climate in last few decades has caused havoc by inducing exxtreme events like draught, floods, erratic rainfalls, landslides etc. which not only harmed human lives but also caused negative effect on food security of our country. Various seasonal changes like longer summers and shorter winters has affected the vegetative growth of apple trees and impacted the blossoming, fruit setting and yield. The present study has taken under consideration all these scenarios and by analysing these finding from the Table 2, it was revealed that apple growers believed in overall that in case of weather parameters, there was increase in annual temperature (84.5%), as there was rise of temperature in summer season (82.5%) and fall in winter season (79%). In case of precipitation, there were fluctuations in hailstorms and snowfall events (76% & 84.5%). In terms of rainfall, there was a change in frequency of rainfall (80.5%), which included heavy rainfall (79%), increase in untimely rainfall (79.5%), and inefficient winter precipitation (77%), also there was also a shift in onset of monsoon (74%), and decline in duration of monsoon precipitation (71.5%) in recent past. In terms of other extreme events, there was an increase in frequency of landslides (86.5%), floods (70.5%) and there were also seasonal changes like longer summer seasons (82.5%) and shorter winter season (87.5%) happened in the recent past. This means that increase in various extreme induced events and other seasonal changes are a yardstick for highlighting the effects of climate change. These findings are quite similar with Raj (2020) and Rani and Prasher (2021).

Table 2: District-wise perceptions of apple growers on various extreme induced events and other seasonal changes due to climate change

(Percent)

Particulars	Mandi	Kullu	Shimla	Overall
A. Weather parameters				
1. Temperature				
1. Increase in annual temperature	86.67	82.86	84.29	84.50
2. Temperature rise during summer season	83.33	81.43	82.86	82.50
3. Temperature fall during winter season	78.33	80.00	78.57	79.00
2. Precipitation				
1. Change in frequency of rainfall	76.67	82.86	81.43	80.50
2. Decline in duration of monsoon precipitation	73.33	70.00	71.43	71.50
3. Shift in onset of monsoon (Early/Late)	71.67	74.29	75.71	74.00
4. Heavy rainfall	78.33	78.57	80.00	79.00
5. Inefficient winter precipitation	75.00	77.14	78.57	77.00
6. Increase in untimely rainfalls	76.67	80.00	81.43	79.50
7. Fluctuations in hailstorm events	70.00	75.71	81.43	76.00
8. Fluctuations in snowfall events	83.33	84.29	85.71	84.50
B. Other extreme induced events				
1. Increase in frequency of droughts	68.33	71.43	70.00	70.00
2. Increase in frequency of landslides	85.00	87.14	87.14	86.50
3. Increase in frequency of floods	68.33	72.86	70.00	70.50
4. Drying up of water sources	46.67	54.29	55.71	52.50
C. Seasonal changes				
1. Longer summer season	83.33	82.86	81.43	82.50
2. Reduced winter season	88.33	88.57	85.71	87.50

Perceptions of apple growers on impact of climate change on apple

From the scrutiny of Table 3, it was revealed that apple growers in overall believed that change in climate had affected the flowering and fruit development stage of apple (81%), as excessive rainfall had reduce the apple productivity (68.5%). Hailstorms were a major problem in apple (70%) and fluctuations in snowfall had affected the chilling hours requirement of apple (73.5%). Extremities in temperature had impacted the apple production as high temperature impacted the quality of the apple fruit (77.5%) which had also increase in variability in the apple yield (71.5%), if necessary adaptive strategies were not taken. Climate change had also changed the cropping pattern of the study area (76.5%), as there were changes in sowing and harvesting of crops (79.5%). In apple, there were changes in flowering time (76.5%), increase in early fruit maturity (78.5%), decrease in fruit size (78.5%), disease incidence (72.5%), and also an observation of new pests (75.5%). These finding are quite simliar with Adhikari *et al.* (2024).

Due to climate change, ecological diversity had been also affected, as there was also a change in the number of insect-pests affecting apple (Increment in their population) (74%)

which had also affected the productivity of apple in overall. This led us to the conclusion that climate change has not only impacted the production, but also the surrounding our environment.

Table 3: District-wise perceptions of apple growers on impact of climate change on apple

(Percent)

Particulars	Mandi	Kullu	Shimla	Overall
1.Effect of climate change on flowering and fruit development stage of apple	76.67	81.43	84.29	81.00
2. Harmful impact of excess rainfall on apple productivity	73.33	65.71	67.14	68.50
3. Shifting of higher chilling varieties of apple towards higher elevations due to climate change	80.00	77.14	78.57	78.50
4. Hailstorms were major problem in apple	71.67	70.00	68.57	70.00
5. Fluctuation in snowfall has affected the chilling hours requirement of apple	75.00	71.43	74.29	73.50
6. Extremities of temperature causing obstacles on apple production	83.33	75.71	74.29	77.50
7. Increase in variability in apple yield due to climate change	70.00	72.86	71.43	71.50
8. Changes in cropping pattern	80.00	74.29	75.71	76.50
9. Changes in growing season	81.67	80.00	77.14	79.50
10. Changes in flowering time	83.33	74.29	72.86	76.50
11. Increase in early fruit maturity	78.33	77.14	80.00	78.50
12. Increase in disease incidence in apple	76.67	71.43	70.00	72.50
13. Increase in number of insect-pests in apple	75.00	74.29	72.86	74.00
14. Any observation of new pests in apple	73.33	75.71	77.14	75.50
15. Introduction of new crops (Cereals, vegetables, fruits etc.)	80.00	80.00	81.43	80.50
16. Small fruit size	76.67	78.57	80.00	78.50

Perceptions of apple growers towards adaptation strategies to cope up with climate change

From the Table 4, it was revealed that apple growers in overall were already using climate adaptive technologies like use of antihail net (100%), use of micro-irrigation (100%), shade nets (100%) to protect apple from weather calamities and in terms of nutrient management, use of FYM (100%), timely use of plant protection chemicals (89.5%), and proper nutrient management (92.5%) was done by them. Use of soil moisture conservation (95.5%), water conservation practices like construction of water tanks (85%), and adoption of multiple cropping (58%) was also done by them to cope up with climate change. All these strategies were also significant in overall. Only in the availing of benefits from subsidies given by government were non-significant as requirement of inputs was quite large in apple

and these benefits were not able to cover them. So, there is a great need of knowledge and passive adaptation to climate change to reduce its effects and to attain higher production in apple as explained by Tripathi and Mishra (2017) in their study on Indian farmers.

Table 4: District-wise perceptions of apple growers towards adaptation strategies to cope up with climate change

(Percent)

Particulars	Mandi	Kullu	Shimla	Overall	Chi-sq value
1. Timely use of plant protection chemicals	86.67	91.43	90.00	89.50	0.000003
2. Proper nutrient management	91.67	92.86	92.86	92.50	0.000000
3. Use of anti-hail nets/ guns	100.00	100.00	100.00	100.00	0.000000
4. Use of soil moisture conservation measures	95.00	94.29	95.71	95.00	0.000000
5. Use of climatically adaptable varieties of apple	86.67	84.29	85.71	85.50	0.000739
6. Use of bio-fertilizers	41.67	44.29	41.43	42.50	0.000000
7. Increase in number of improved livestock adaptable to climate change	56.67	50.00	61.43	56.00	0.000000
8. Reforestation	53.33	62.86	61.43	59.50	0.000000
9. Use of FYM	100.00	100.00	100.00	100.00	0.000000
10. Use of water conservation practices	76.67	88.57	88.57	85.00	0.001323
11. Use of rain-harvesting techniques	53.33	61.43	62.86	59.50	0.000000
12. Use of water efficient irrigation techniques (Micro-irrigation)	100.00	100.00	100.00	100.00	0.000000
13. Use of shade nets	100.00	100.00	100.00	100.00	0.000000
14. Diversification of crops	61.67	61.43	64.29	62.50	0.000032
15. Natural farming	38.33	35.71	37.14	37.00	0.000000
16. Adoption of multiple cropping	43.33	67.14	61.43	58.00	0.000000
17. Availing crop insurance services	61.67	60.00	58.57	60.00	0.000001
18. Benefits of subsidies	65.00	68.57	78.57	71.00	0.169603^{NS}

Note: Chi-sq value was tested at 1% level of significance

Conclusion

The present study has led us to the conclusion that impact of climate change has increased in last few decades and it has negatively affected the yield of apple in our state. It has led to vegetative vigour at the cost of apple yield, reduce sugar content and elevate the fruit acids leading to tarter tasting fruits. Changes in the timing of flower and fruit set disrupt the fruit development, leading to significant yield losses. Similarly, timely water availability poses potential risks to apple orchards as reduced rainfalls and fluctuating precipation patterns has impacted the water supply and irrigation practices. Additionally, the

vulnerability of apple orchards to extreme weather events such as erratic rainfall, hailstorms and unseasonal rainfall etc. results in physical damage of fruits and also affect the transportation and market access as it was happened in our state last year. The suitability of certain apple cultivation areas has also shifted due to changing climatic conditions. So, there is a great need among apple growers to adapt their technologies to climate change like exploring new varieties which are high yielding and adaptable to climate change and also going for crop diversification to deal with financial losses. Also, government should improve their supportive policies and come up with effective mitigative and adaptive measures which are significant for safegurading the productivity of apple in Himachal Pradesh.

References

Adger WN. 1999. Social vulnerability to climate change and extremes in coastal Vietnam. *World Development*.27:249-269.

Adhikari D, Prasal R, Lamichhane S, Gautam D, Sharma S and Acharya S. 2021. Climate Change Imapcts and Adaptation Strategies in Trans-Himalaya Region of Nepal. *Journal of Forest and Livelihood.*

Adhikari S, Timilsina RH, Panthee AA and Sapkota A. 2024. Farmers' Perceptions of the impact of climate change on apple production in lower Mustang, Nepal. *Archives of Agriculture and Environmental Science.* 9:8-13.

Arundhati and Bhagat RM. 2020. Impact of Climate Change on apples production: World scenario. *Journal of Pharmacognosy and Phytochemistry.* 9:1219-1228.

Ashcroft GL, Richardson EA and Seeley SD. 1977. A statistical method of determining chill unit and growing degree hour requirements for deciduous fruit trees. *Horticultural Science.* 12:347-348.

Awasthi RP, Verma HS, Sharma RD, Bhardwaj SP and Bhardwaj SV. 2001. Causes of low productivity in apple orchards and suggested remedial measures. In: Jindal KK, Gautam DR, editors. Productivity of Temperate Fruits. Dr Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan (HP). 1-8.

Birthwal PS, Khan MT, Negi DS and Aggarwal S. 2014. Impacts of climate change on yields of major food crops in India: Implications for food security. *Agricultural Economics Research Review.*27:145-155.

Bryan E, Deressa TT, Gbetibouo GA and Ringler C. 2009. Adaptation to climate change in Ehiopia and South Africa: Options and constraints. *Environmental Science & Policy*.12:413-426.

Chand H, Verma SC, Bhardwaj SK, Mahajan PK and Sharma G. 2015. Assessment of chill units accumulation and apple productivity under changing climatic condition in high hill temperate wet zone of North-Western Himalayan. *Journal of Hill Agriculture.* 2:229-233.

Charmaker S and Mijar D. 2009. Local perspectives on a global phenomenon: Climate change in Eastern Tibetan villages. *Global Environmental Change.*19:156-166.

Economic Survey of Himachal Pradesh. 2024. Economic and Statistics Department, Himachal Pradesh. https://himchalservices.nic.in/en-economic_survey_2023-24.pdf

Garg G. 2015. *Assessment of Climate Change Vulnerabilities in Agriculture: A Case Study of Solan District.* MSc Thesis. Department of Social Sciences, College of Forestry, Dr. Yashwant Singh Parmar University of Horticulture & Forestry.97p.

Jindal KK, Chauhan PS and Mankotia MS. 2000. Apple productivity in relation to environmental components. In: Jindal KK, Gautam DR, editors. Productivity of Temperate Fruits. Dr Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan (HP). 12-20.

Kumar A and Sharma P. 2013. Impact of Climate variation on Agricultural productivity and Food Security in Rural India. *Economics:The open –Access, Open-Assessment E-journal*.34:2013-2043.

Mahato A. 2014. Climate Change and its Impact on Agriculture. *International Journal of Scientific and Research Publications*.4:122-123.

NHB. 2024. Annual Production of fruits. National Horticultural Board. http://www.nhb.org

Prasad HC. 2013. Handbook on Climate-Resilient Horticulture: Adaptation and Mitigation Strategies. Springer.

Raj D. 2020. Assessment of Technical Efficiency of Apple Cultivation in Himchal Pradesh. PhD Thesis. Dr Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan (HP). 137p.

Rani S and Prasher RS. 2020. Analysis of Vulnerability Indices in Hamirpur District of Himachal Pradesh. *International Journal of Farm Sciences.* 10:33-44.

Rani S and Prasher RS. 2021. Farmers' Perceptions towards climate change and its adaptation strategies in Hamirpur District of Hiamchal Pardesh. *Indian Journal of Economics and Development.* 17:77-85.

Rani S. 2019. Impact Assessment of Climate Change on Agricultural Economy in Low Hills of Himachal Pradesh. MSc Thesis. Dr Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan (HP). 91p.

Sarkar S and Padaria RN. 2010. Framers' awareness and risk perception about climate change in coastal ecosystem of West Bengal. *Indian Research Journal of Extension Education*.2:32-38.

Shankara MH, Shivamurthy M and Manjunatha BN. 2012. Farmers' perception of climate change and its impact on agriculture in Karnataka. *Mysore Journal of Agricultural Sciences*.4:886-890.

Sharma N. 2015. Impact of cliamgte change on temperate fruits and nuts production. *Souvenir and Abstracts the National Conference on Temperate Fruits and Nuts.* Central Institute of Temperate Fruit Horticulture, Srinagar (J&K).

Sharma NC, Sharma SD, Verma S and Sharma CL. 2013. Impact of changing climate on apple production in Kotkhai area of Shimla district, Himachal Pradesh. *International Journal of Farm Sciences.* 3:81-90.

Shaul MP. 2018. Handbook of Fruit Set and Development. 2018.

Sheikh BA and Baba SH. 2023. Effects of Climate Change on Apple Farming in Kashmir Valley. *International Journal of Agriculture and Animal Production.* 3:12-17.

Shivani, Tamanna and Rani S. 2023. Wood Biomass and Bioenergy: Utilization and Technological Innovation. *Advances in Forestry and Agroforestry.* 1:1:19.

Singh S, Sharma DP and Chand H. 2016. Impact of Climate Change on Apple Production in India: A Review. *Current World Environment.* 11:251-259.

Sugiura T, Ogawa H, Fukuda N, Moriguchi T. 2013. Changes in the taste and textural attributes of apples in response to climate change. *Scientific Reports.* doi:10.1038/srep02418

Tripathi A and Mishra AK. 2017. Knowledge and passive adaptation to climate change: An example from Indian farmers. *Climate Risk Management.*16:195-207.

Venkateswarlu B. 2009. Climate change and sustainable agriculture: securing the small and marginal farmer in India. *Human impact of climate change: policy notes for parliamentarians.* Centre for Legislative Research and Advocacy. New Delhi. 4p.

Wani PS, Jakula SV, Singh D. 2017. Doubling Farmers' Income. *Kisan Mitra.* 160pp.