

Perceptions of apple growers on Impact of Climate Change on Apple Production in Mid and High Hills of Himachal Pradesh, India

Abstract

The present study entitled “Perceptions of apple growers on Impact of Climate Change on Apple pProduction in Mid and High Hills of Himachal Pradesh” had made an attempt to analyse the trends in temperarture, rainfall and apple productivity, and perceptions of apple growers on impact of climate change on apple production. The findings of the study revealed that the temperarure and rainfall has followed a fluctutating trend over the years which caused an negative impact on the productivity of apple since it had been reduced by 11 percent in last few 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 not to mention long-term changes in mean temperature (75%) and mean rainfall (75%). Climate change had furthermore 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%), coupled with an observation of new pests (75.5%). 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. Therefore, 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. Additionally, 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.

Keywords: Climate change, apple production, erratic rainfall, climatic vulnerability, adaptation strategies

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, volcanic 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 extrapolating global climate change has caused increase in level of greenhouse gases which has furthermore elevated the temperatures and changes in spatiotemporal distribution of rainfall (Li *et al.* 2020). 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 moreover 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). Besides, impact of climate change can furthermore 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 attaining 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 as well 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 furthermore 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). Moreover, effective implimentation of adaptive measures is also necessary for deal with climate change (Bryan *et al.* 2009; Venkateswarlu, 2009). The apple growers' adaptation to climate change is further modulated by their exposure to multiple stressors like changes in agricultural policy, labour condtions, cost of input and market prices and their decision making is also affected by non-climatic factors too (Fujisawa and Kobaayashi, 2011 and Fujisawa *et al.* 2015).

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), moreover, DSS (Decision Support System) is over and above 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.

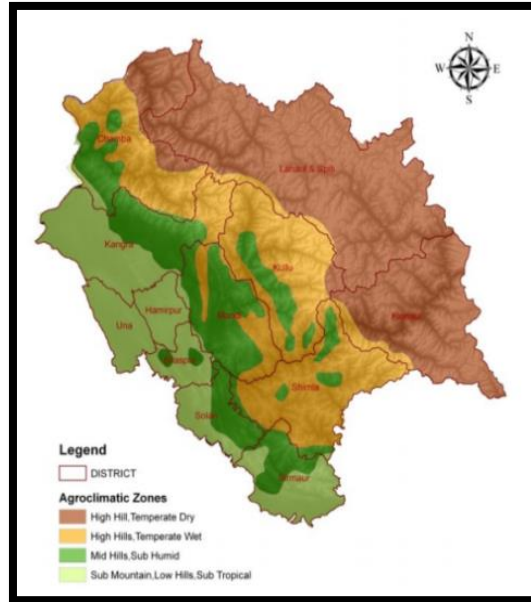


Fig 1: Different agro-climatic zones of Himachal Pradesh

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

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

Where;

O_i is the observed value, E_i is the expected value and $i = 1, 2, 3, \dots, n$; 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_{Tab}^2 is 6.635 and the decision rule is as follows: Reject H_0 if $\chi_{Cal}^2 \geq 6.635$.

Results and discussion

Trends in average annual temperature in last decades in himachal Pradesh

The trends in average annual temperature revealed that it had followed a fluctuating trend over the years (Fig 2). The temperature has increased 2.9 percent over the years which led us to the conclusion that the summer has become more warmer and the winter has become more cooler attributable to climate change.

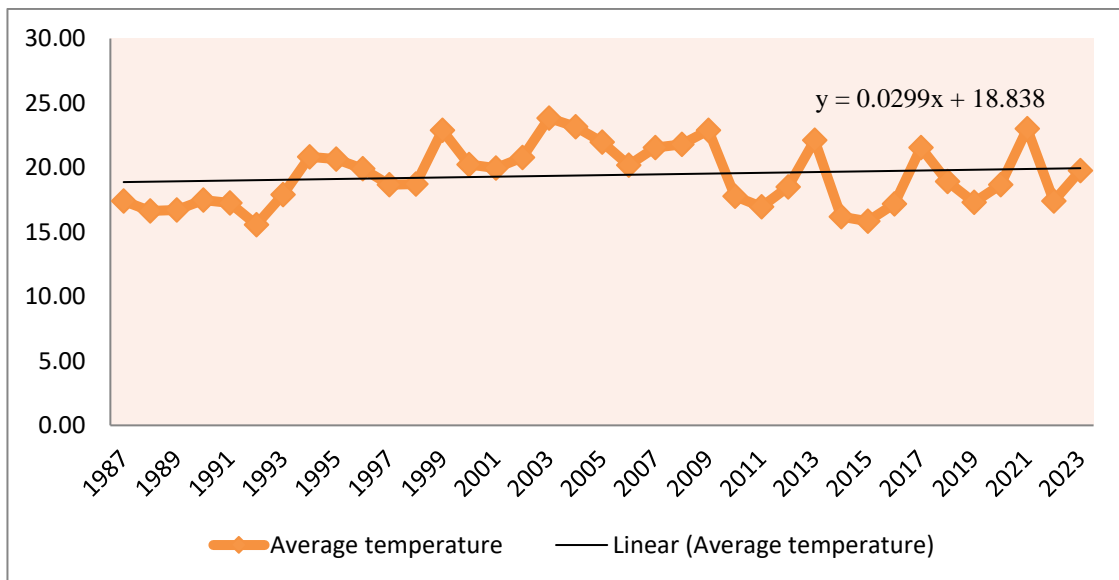


Fig 2: Trends in average annual temperature from year 1987 to 2023

Trends in rainfall pattern in Himachal Pradesh

It is a well-known phenomenon that the seasonal pattern for higher elevation states like Himachal Pradesh is quite different from other states (Jaswal *et al.* 2005). So, the trends in rainfall over the years revealed that it has followed a fluctuating trend over the years (Fig 3). The rainfall has changed by 17.2 percent with time which means that the rainy days has increased over the years, but the intensity has followed a fluctuating trends which led us to the conclusion that in some of the years, the rainfall was more than sufficient which had led to flood like conditions and in some years, it was so deficient which had led to draught like conditions and one of the main reasons for these fluctuations was climate change which has led to shift apple belt towards upper regions of Himachal Pradesh.

Trend in apple productivity in Himachal Pradesh

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 (Fig 4). 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.

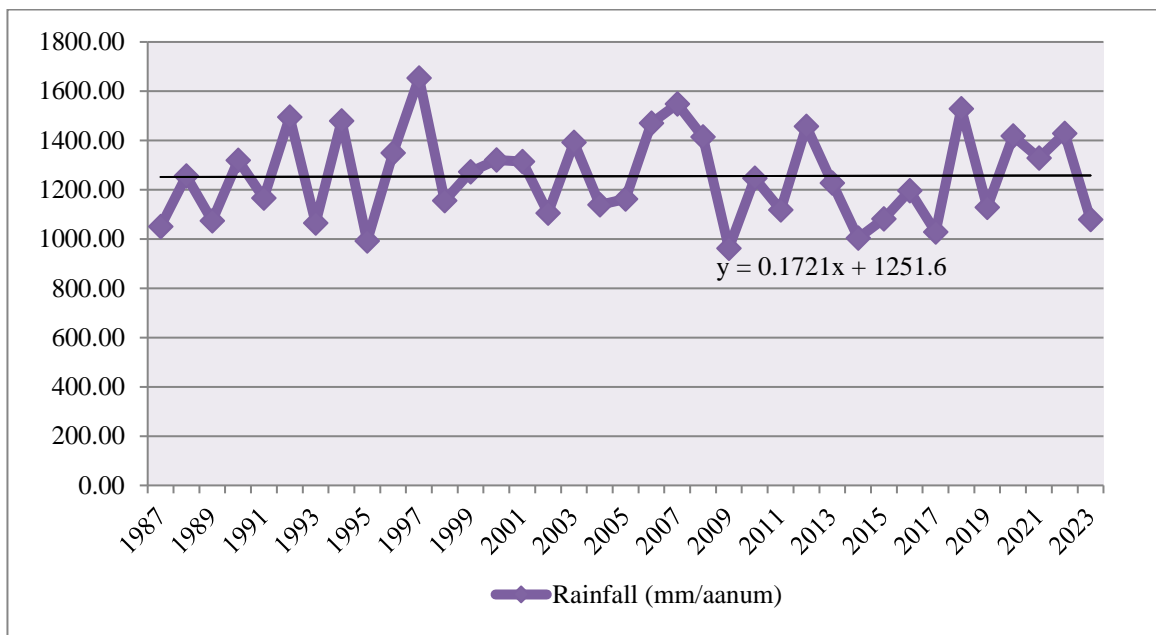


Fig 3: Trend in rainfall pattern from year 1987 to 2023

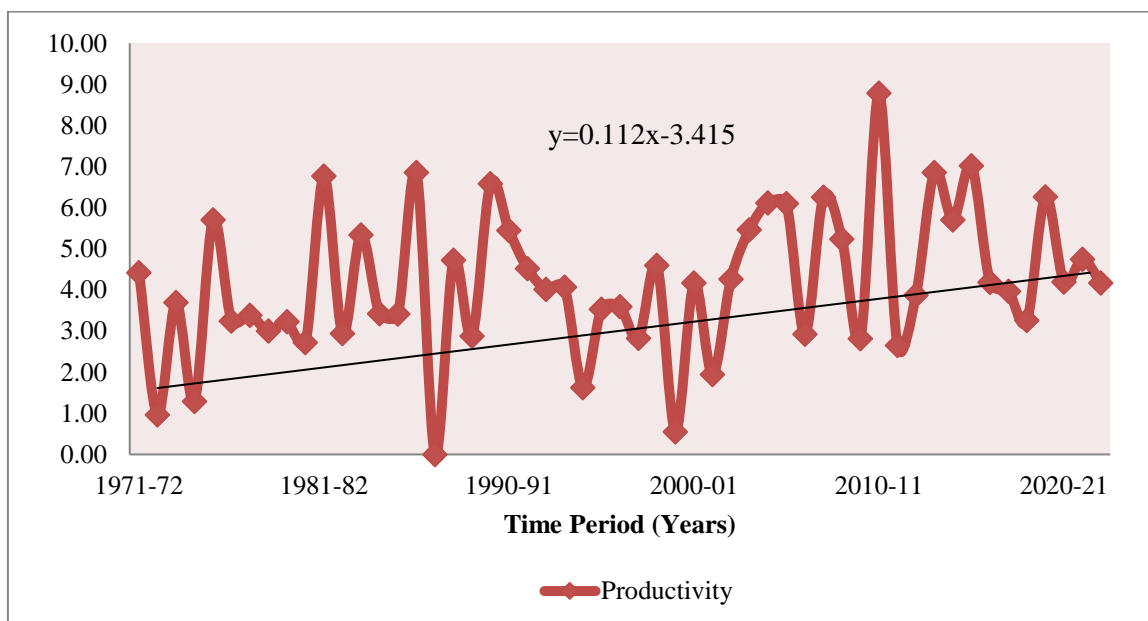


Fig 4: Trend in apple productivity from 1971-72 to 2021-22

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, precipitation, 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 additionally 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

Particulars	(Percent)			
	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 extreme events like draught, floods, erratic rainfalls, landslides etc. which not only harmed human lives but on the top of 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 withal 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

Particulars	(Percent)			
	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 additionally 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 not to mention an observation of new pests (75.5%). These finding are quite simliar with Adhikari *et al.* (2024). As a consequence of 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 over and beyond the surrounding our environment.

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

Particulars	(Percent)			
	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

Particulars	(Percent)				
	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}
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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. The changing scenarios of temperature and rainfall have affected the growth and development of apple tree. It has led to negative effect on vegetative vigour at the cost of apple yield, further reducing the 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, untimely water availability poses potential risks to apple orchards as reduced rainfalls and fluctuating precipitation 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. Furthermore, changes in irrigation, soil management techniques, as well as tree pruning will also further help in increasing apple production. In long-term strategies, introduction of new varieties which can mature early or late, or draught tolerant varieties in apple will also help in dealing with climate change in future. The application of integrated soil-fruit-climate management (ISFCM) is the need of the hour. Accordingly, our 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.

Limitations of the study

The primary data collected from apple growers is memory-based which might be inaccurate in some scenarios. Also, the data on perception was collected for one year (2022-23) which might be inefficientt for analysing last decade's climatic patterns. Similarly, climate change might be different in other areas than the selected area for the study.

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