PRIMARY ARTICLE

# Horticulture Crop Production In North-western Himalayas Under Changing Climate Scenario

Bhardwaj Satish Kumar And Sharma Som Dev


## ABSTRACT

During the recent past, weather patterns all over the world have changed and Himachal Pradesh of North-Western Himalaya is no exception. The trend analysis of temperature and precipitation data was done by taking data of 1973-1990 from wet temperate and 1971-90 duration from sub temperate region as baseline which was further divided into two periods i) 1991-2000; ii) 2001-2011 and variation was analysed season wise. In the sub temperate region maximum temperature has increased in all the seasons, however highest increase of 3.11oC was noticed in winter season during 2001-2011 period from the base years of 1971-90. The average minimum temperature was found to decrease over the base period of 1971-90. The maximum decrease of 1.3oC over the base period was noticed in autumn season during the period of 2001-2011. In the region the period 2001-2011 experienced decrease in the rainfall during summer, spring and winter seasons, however, the maximum decrease of 115.23 mm was noticed in summer season. In wet temperate to dry temperate regions both maximum and minimum temperatures have increased and winters have become warmer. Among all fruits, apple is the main crop of the state occupying the place of pride in its economy. However, the rise in temperatures and decreased snowfall over years has adversely affected apple cultivation in the state. Earlier snowfall was a regular phenomenon in apple growing areas but since 1973-1985 (baseline) a reduction in the snow fall from 430 cm to 51.33 cm during the period of 2006-2010 was recorded. The un-conducive weather during fruit setting and development in apple has reduced the apple productivity of the region. Surprisingly, the orchards below 1500 m elevation have been rendered unproductive. In the sub- tropical climate of foothills of Himalayas the mango is an important crop and is being influenced by frequent frost events. The cold waves during winter months also found to influence the vegetable crops of the region. To adapt to changing climate farmers have shifted to cultivation of pomegranate, kiwi and off-season vegetables. In sub-tropical zone, the regular frost injury to mango plants has become common. The farmers of this zone have shifted to protected cultivation of flowers and vegetables to save their livelihoods. Therefore, accepting change and getting in tune with nature by following scientific mitigation and adaptation strategies seem to be the key to survival and prosperity of mountain farmers.


**KEYWORDS :**
Apple, Mango, Vegetable Crop, Snowfall And Frost .

## INTRODUCTION

Horticulture in Himachal Pradesh consists of diverse farming activities viz. growing of fruits, vegetables and floriculture, which are cultivated in a wide range of production regions because of the diverse micro-climates. All horticultural crops are sensitive to temperature and commercial crops of the state e.g. apple in temperate and mango in sub-tropical region have specific temperature requirements for their growth and development. Based on temperature requirements, the fruit trees grown in Himachal Pradesh can be categorized into sub-tropical, sub-temperature/warm temperate and

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temperate.

Rising global temperature has triggered large-scale changes in the energy exchange processes affecting the atmospheric circulation and precipitation patterns (Fallot et al., 1997, Zhai et al., 1999, Beniston, 2003). The studies in Nepal Himalaya (Shreshtha et al., 2000) and upper Indus basin in the North Western Himalaya (Archer and Fowler, 2004) have shown minor and statistically insignificant variations in the precipitations in the last century.

Air temperature is generally recognized as a good indicator of the state of climate globally because of its ability to represent the energy exchange process over the earth's surface with reasonable accuracy (Thapliyal and Kulshreshta, 1991). In the North-Western Himalayan region, very limited number of studies explaining the climate change in different mountain states e.g. Himachal Pradesh have been done for the want of adequate instrumental data. Hence, the present study was conducted to study changing climate situations and its impact on horticulture.

## Material And Methods

For better understanding of potential impacts of the climate change in data sparse state, trend analysis of temperature and precipitation data available from following two stations in Himachal Pradesh a true representative of North-Western Himalayas was done. Variations in temperature and precipitation was analysed season wise i.e. summer (June, July, August), autumn (September, October, November), winter (December, January, February) & spring (March, April, May). The meteorological data w.e.f. 1973-1990 for wet temperate and 1971-90 for sub temperate region was taken as baselines (Table 1). For better analysis of the climate conditions the data was divided into two periods i) 1991-2000; ii) 2001-2011 (Table 2 & 3).The snow fall data recorded in wet temperate region was grouped on five year basis and was compared with baseline period of 1973-1985. Survey was conducted in different parts of the state to identify the crops vulnerable to changing climate situations and to know the adaptation strategies being followed by the mountain farmers. During the survey impact of the climate on the major fruit and vegetable crops of the region was also recorded.

Table 1.Location of weather data stations

| S. No. | Region | Altitude (m) | Latitude/Longitude | Data Period |
|---|---|---|---|---|
| 1 | Wet temperate | 2300 | $31^0$06'N/$77^0$10'E | 1973-2011 |
| 2 | Sub temperate | 1275 | 30.02$^0$N/77.05$^0$E | 1971-2011 |

## Results And Discussion

Climate change scenario of sub temperate and wet temperate zone

In sub temperate region, during the period from 2001-2011 maximum temperature has increased in all the seasons, however highest increase of 3.11oC was noticed in winter months from the base years of 1971-90 which was followed by 1.570C increase in spring season (Table 2). Whereas, the average minimum temperature was found to decrease over the base period of 1971-90. The maximum decrease of 1.3oC was noticed in autumn season during the period of 2001-2011 followed by 1.24 oC in winter season in the same period over the base years of 1971-90. In the region, the decade 2001-2011 experienced decrease in the rainfall during summer, spring and winter seasons, however, the maximum decrease of 115.23 mm was noticed in summer over the base period followed by 88.31mm in spring and 25 mm in winter season. However, an increase in rainfall to the tune of 53.37mm was noticed in the autumn season of the same decade over the base period. The sub temperate region as a whole is therefore, experiencing scanty rains during winter, summer and spring months resulting water scarcity which is affecting the crops.

Table 2.Season wise decadal changes in mean maximum,minimum temperature(0C) and total rainfall (mm) with respect to baseline 1971-1990 in sub- temperate region of North-Western Himalayas.

| Season | Maximum Temperature | | | Increase/ Decrease (+/-) | | Minimum Temperature | | | Increase/ Decrease (+/-) | | Total Rainfall | | | Increase/ Decrease (+/-) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1971-1990 | 1991-2000 | 2001-2011 | 1991-2000 | 2001-2011 | 1971-1990 | 1991-2000 | 2001 - 2011 | 1991-2000 | 2001-2011 | 1971-1990 | 1991-2000 | 2001-2011 | 1991-2000 | 2001-2011 |
| Winter | 17.43 | 18.42 | 20.54 | +0.99 | +3.11 | 4.25 | 3.5 | 3.01 | -0.75 | -1.24 | 156.98 | 171.2 | 131.98 | +14.22 | -25.00 |
| Spring | 27.23 | 26.97 | 28.8 | -0.26 | +1.57 | 12.38 | 12.48 | 12.60 | +0.10 | +0.22 | 224.83 | 163.88 | 136.52 | -60.95 | -88.31 |
| Summer | 29.23 | 28.9 | 29.48 | -0.33 | +0.25 | 19.89 | 19.81 | 19.47 | -0.08 | -0.42 | 687.38 | 674.15 | 572.15 | -13.00 | -115.23 |
| Autumn | 25.47 | 25.46 | 26.57 | -0.01 | +1.10 | 12.16 | 11.75 | 10.86 | -0.41 | -1.30 | 141.67 | 175.82 | 195.04 | +34.15 | +53.37 |

Table 3 .Season wise decadal changes in mean maximum, minimum temperature(0C) and total rainfall (mm) with respect to baseline 1973-1990 in high hill wet temperate region of North -Western Himalayas

| Season | Maximum Temperature | | | Increase/ Decrease (+/-) | | Minimum Temperature | | | Increase/ Decrease (+/-) | | Total Rainfall | | | Increase/ Decrease (+/-) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **1973-1990** | **1991-2000** | **2001-2011** | **1991-2000** | **2001-2011** | **1973 - 1990** | **1991-2000** | **2001-2011** | **1991-2000** | **2001-2011** | **1973-1990** | **1991-2000** | **2001-2011** | **1991-2000** | **2001-2011** |
| Winter | 10.14 | 11.97 | 14.12 | +1.83 | +3.98 | 1.79 | 1.75 | 3.25 | -0.04 | +1.46 | 80.19 | 87.11 | 81.34 | +6.92 | +1.15 |
| Spring | 18.91 | 20.67 | 21.71 | +1.76 | +2.80 | 8.79 | 8.65 | 10.53 | -0.14 | +1.74 | 235.37 | 228.39 | 194.69 | -6.98 | -40.68 |
| Summer | 22.46 | 23.64 | 23.67 | +1.18 | +1.21 | 14.13 | 14.13 | 15.01 | - | +0.88 | 777.99 | 767.73 | 680.79 | -10.26 | -97.2 |
| Autumn | 19.0 | 20.51 | 20.41 | +1.15 | +1.41 | 9.05 | 8.91 | 10.30 | -0.14 | +1.25 | 180.5 | 185.95 | 200.09 | +5.45 | +19.59 |

In wet temperate region of high hills of North-Western Himalayas, the maximum temperature during the period 1991-2000 and 2001-2011 compared over the baseline 1973-1990 has shown increase in all the seasons (Table 3). Among both the decades studied the highest increase of 3.980C in maximum temperature was recorded during the period from 2001-2011 in winter season which was followed by spring season in the same decade. The perusal of data presented in the table 3 indicated that in this part of Himalayan region winters have become warmer. In the 2001-2011 decade a rise in minimum temperature in the range of 0.88 to 1.740C was noticed, however the highest increase (1.740C) over the base period in this parameter was recorded during spring season. The total rainfall was found to decrease during summer and spring months of both the decades. The highest decrease of 97.2 mm was recorded during summer season of 2001-2011 period. Wet temperate hills of this part of Himalayas have experienced drastic reduction in snowfall since the base line period of 1973-1985 (Figure 1). In the baseline period, the region used to receive average snow fall of 430 cm beginning from November i.e. early winter season. It has now squeezed to about 51.33 cm during the period of 2006-2010 and in the months of January and February only. Non-availability of early winter snowfall in March is inducing early flowering in temperate fruit crops due to early warming effect.

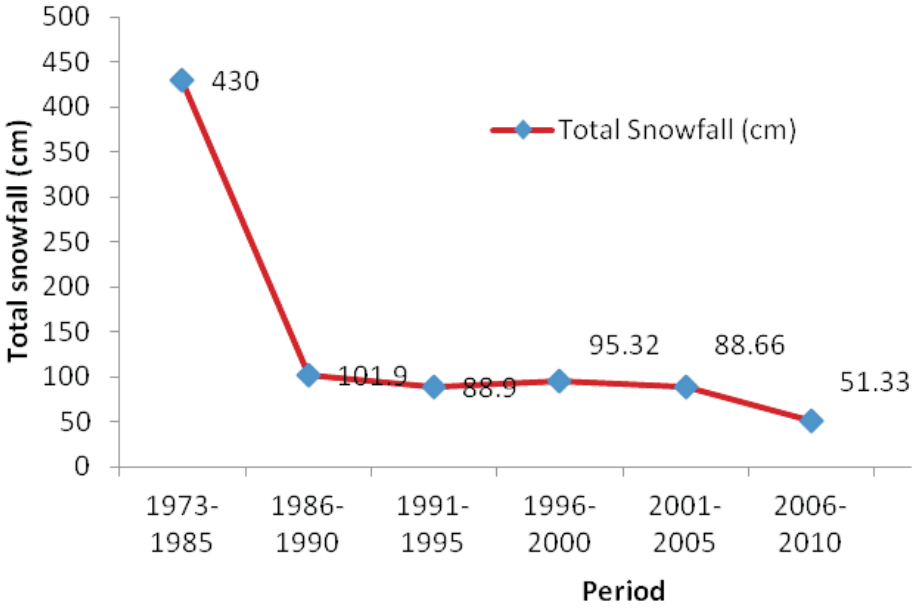


Figure 1. Snowfall pattern of wet temperate region of North-Western Himalaya

*Fruit and vegetable crop production under changing climate conditions*

The distribution of horticulture crops in the region is influenced mainly by climate than any other factor. Rising temperatures, reducing snowfall and rainfall events as well as changes in monsoon pattern is affecting horticulture and is a matter of serious concern for farmers of North-Western Himalayan region. Climate change is projected to affect the horticultural crops and these impacts can be at any stage of crop growth and development, thus influencing the quality and yield.

Apple is the predominant temperate fruit crop of North-West Himalayas. Winter temperatures and precipitation especially in the form of snow are very crucial for induction of dormancy, bud break and ensuring flowering in apples. Apple requires minimum of 1200 chilling hours during winters for yielding a good crop especially for standard cultivars like Royal Delicious. Short chilling hours during winters result staggered, delayed, sparse flowering and ultimately low productivity. Early winter chilling has more beneficial effect on productivity as compared to late chilling contribution. Cumulative effect of more than 1600 chilling hours, good snow and well distributed winter rains resulted in a good crop year of 1998 and 2011. In contrast during 1999 and 2009 only about 958 chilling hours were received which were supplemented by late snow and rains in January-February and almost dry and warm early winter resulted in a poor crop year.

Flowering period is the most sensitive stage of plant development in apple so far as climatic conditions are concerned. The flowering in the largely grown apple variety Royal Delicious occurs in the month of April during 4th to 26th April. During this period the ambient air temperature should remain between18-220C. However, the temperature fluctuations and hails coinciding with full bloom result poor fruit set in apple. The bud break and petal fall is the most sensitive stage in apple when hail can reduce the prospective of good crop to almost off year. During 1996, 1998 and 2011 the temperature at the time of flowering remained in the optimum range and mild rains during post bloom period and no hails resulted good crop. In contrast the maximum temperature from 24-270C during flowering and dry as well as desiccating bloom period resulted in poor apple crop during 1999 and 2009. In the year 1997 and 2012 the hails coinciding full bloom resulted in poor fruit set. In addition to this spring frost coinciding the flowering flushes especially the full bloom affects the fruit set adversely (Table 4).

Due to more rise in temperature during winters in wet temperate regions, apple cultivation has been impacted adversely, especially in mid altitudinal range of 1500 m – 2000 m amsl. The rise in temperature and reduced snowfall (Table 3 and Figure 1) has made this part

of region vulnerable to climate change as result apple farming has been abandoned in the area falling upto 1500 m amsl. Awasthi et al. (1986) have also indicated that irregular bearing behavior of apple variety Starking Delicious is largely influenced by climatic conditions. The rise in temperature however, has created more moderate conditions for apple cultivation in Lahaul-Spiti and Kinnaur districts. This can be viewed as positive impacts of climate change in dry temperate climate above an elevation of 2472 m amsl.

The air temperature, cold wave and frosts are decisive factors in plant growth and development of subtropical fruit like mango. This crop is very sensitive to frost. Mango grows well in temperatures ranging from 23.8-29.40C. The temperature during inflorescence is crucial. Cool temperatures and frosting during inflorescence development reduce the number of perfect flowers drastically. However, it can tolerate temperatures as high as 480C during the period of fruit development and maturity. In mango, low temperature (2 to 11.5 oC), high humidity (> 80%) and cloudy weather in January & February months found to delay panicle emergence. The unseasonal erratic rains and increased frost events is affecting mango production in the subtropical regions of North-Western Himalayan region. In low hills – sub-tropical zones the regular frost events may be due to the increased gap between maximum and minimum temperature has affected the mango orchards. During the year 2006-2007 mortality of mango plants due to frost ranged between 40-83 %. The impact of the frost was noticed more on younger plantations as compared to the older ones.

The succulent vegetable crops are highly sensitive to climate conditions like heat, drought and cold waves. The rise in temperature affects crop duration, flowering, fruiting, ripening and quality with reduced productivity and economic yield. In tomato which is one of the major commercial crop this region, the high temperatures after pollen release decreased fruit setting, yields and seed set even when pollen was produced under optimal conditions. High temperature above 280C noticed to induce maximum flower and fruit drop in tomato. However, in high altitudes vegetable yields are expected to increase due to small increase in temperature as a result of increased length of growing period. Not only the high temperatures but low temperatures have also influenced vegetable production in the region. The cold wave during December 2002 and January 2003 noticed to cause considerable damage to brinjal, tomato and potato crops of the region.

Table 4.Apple crop performance with respect to changing weather conditions in wet- temperate region of North-Western Himalaya

| Good Crop Year | Weather Conditions |
|---|---|
| 1996 and 1998 | Well distributed winter rains<br>Maximum temperature at flowering remained 18-22 $^0$C<br>Spring rains were in post bloom period<br>Mild rains just before bloom period |
| 2010-2011 | Well distributed winter rains |
| Poor Crop Year | |
| 1997 | Hails coinciding full bloom resulted poor fruit set |
| 1999 | Dry and warm early winters<br>Late snowfall/rainfall, less chilling hours<br>Maximum temperature at flowering was in the range of 24-27 $^0$C<br>Bloom period remained dry and desiccating |
| 1999 | Dry and warm early winters<br>Late snowfall/rainfall, less chilling hours<br>Maximum temperature at flowering was in the range of 24-27 $^0$C<br>Bloom period remained dry and desiccating |
| 2009-2010 | Late and less snowfall and drought conditions resulted poor crop |
| 2011-2012 | Hails coinciding full bloom and fruit development stage resulted poor fruit set and poor quality of the left over crop |

## *Adaptation Strategies*

With apple production being greatly affected, mountain farmers are steadily moving towards other crop options. Farmers have shifted to cultivation of pomegranate, kiwi and vegetables like tomato, peas, cauliflower, cabbage and broccoli etc. In subtropical low hill region production of mango is being greatly affected by frequent occurrence of frost. Farmers in order to save their livelihoods have opted for protected cultivation of vegetables and flowers in a big way.

## Conclusions

The rising temperature and reduced precipitation is bound to impact horticultural crops of the region. The impacts can be at any stage of crop growth and development, thus influencing the quality and yield. There is an urgent need to focus attention on studying the impacts of climate change on growth, development, yield and quality of horticultural crops. The focus should also be on development of adaptation technologies and quantify the mitigation potential of horticultural crops. Changing climate in North-Western Himalayan region brought forth new problems and questions, the solutions to which will be generated by combining farmers' ingenuity and new technologies. However, accepting change and getting in tune with nature seems to be the key to survival and prosperity of the mountain farmers.

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