DOI : 10.5958/0974-0112.2015.00003.1

Indian J. Hort. 72(1), March 2015: 14-20

Impact of climate variability on apple production and diversity in Kullu valley, Himachal Pradesh

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ABSTRACT

The study assessed the impact of climatic factors on productivity and biodiversity of apple in Kullu valley area. The secondary meteorological data was used to evaluate the impact of climate change on apple diversity with the help of correlation, trend analysis, step up regression and Utah model. The annual average maximum temperature of lower Kullu valley showed increase of 1.2°C in the period of 1985-2009. Winter temperature and summer temperature were found to be increasing at the rate of 0.09°C and 0.06°C per year, respectively. A decreasing trend of rainfall was observed during the winter months. The productivity of apple crop during 1985-2009 showed a cyclic pattern with an overall decreasing trend of 0.4 tonnes/ha. The productivity sensitivity analysis with maximum temperature showed a negative rate of 3.89 every year. Regression analysis revealed that minimum temperature of January, February and November, rainfall of December, and maximum temperature for March and October were important factors to predict the apple yield. The farmers' perception revealed adverse effects on apple biodiversity due to change in climatic conditions. The farmers reported that change in the snowfall pattern led to depletion and shifting of ecological niche of traditionally and commercially important apple varieties and an increase in low chill cultivars. Apple growers specifically in lower Kullu valley switched over to alternate crops and some preferred shifting their orchards to higher altitudes. Cumulative chill units showed a decrease of 9.52 in negative and 6.5 chill units every year in Positive chill units hours of Utah model in Kullu district due to increase in temperature.

Keywords: Apple, biodiversity, climate change, chill units.

INTRODUCTION

Apple is the leading cash crop in Himachal Pradesh occupying about 47% of the total area under fruits and 72% of total area under temperate fruits, contributing about 75% of total fruit production in the state and more than Rs. 987 crores towards the Gross State Domestic Product (GSDP) and projected to increase at the rate of 9.15 per cent per annum in XII Five Year Plan with technological interventions (Anon, 1). The production level has gradually touched to 892.1 metric tonnes with 8.79 tonnes/hectare productivity in 2010-11 (Anon, 2). In Himachal Pradesh, evidences of climate change could be clearly deciphered by changes like receding snowfall in the Himalayas and shifting of temperate fruit belt to upper reashes, adversely affected productivity of apples, changes in rainfall pattern, shifting and shortening of *Rabi* season (Rana *et al.*, 12). Apple holds the potential to transform the economy of the tribal people in Spiti valley with good returns from the apple orchards as compared to wilt and blight prone cash crops of peas and potato (Sharma *et al.*, 13). Problems of climate change also vary in nature and intensity across mountain regions, with higher elevation regions experiencing more rapid temperature rise (Shrestha and Devkota, 14). During the past few decades, the mountain areas have been severely affected by the climate change influencing the crops and cropping pattern. Thus, the assessment of climate change impacts on agriculture has acquired a special significance in mountain area. In the present study an attempt has been made to assess the impact of climatic factors on the productivity and biodiversity of apple in Kullu valley area.

MATERIALS AND METHODS

The present study was carried out in Kullu valley area representing mid-hill sub-humid agro-climatic zone of Himachal Pradesh in the year 2009-10 to relate the weather parameters with apple cultivation facing climate change. This zone represents 16.0% of the total geographical area of Himachal Pradesh. The primary data used in the study were generated through a well structured and pre-tested schedule by questionnaire method from 30 apple growers (large, marginal and small) where the impact of changing climate was more pronounced. The questions were structured on different aspects to extract the detailed information on climate change, its impacts on apple

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productivity, shifting trends and strategic measures to combat the change. The secondary meteorological data for climatic parameters (temperature and rainfall) was collected from the records of regional research station at Bajaura maintained for the period of 25 years, *i.e.* 1985-2009. Apple area and production data for the corresponding period was collected from the Department of Horticulture, Kullu. The trends were worked out using the standard procedure for maximum temperature, minimum temperature, and rainfall and apple productivity. These trends were then interpreted and analysed to obtain the rate and amount of change in each parameter to examine the accuracy of perceptions of the farmers. The effective apple chill units were worked out using temperature data using UTAH model (Byrne and Bacon, 4) because it introduces the concept of relative chilling effectiveness and negative chilling accumulation (or chilling negation) as follows:

Temp. (°F) for 1 hour	Temp. (°C) for 1 hour	Chill unit
< 34	<1.11	0.0
35-36	1.6 – 2.2	0.5
37-48	2.7 – 8.8	1.0
49-54	9.4-12.2	0.5
55-60	12.7-15.5	0.0
61-65	16.1-18.3	-0.5
> 65	>18.3	-1.0

However, because of the abundance of high winter temperatures (temperatures >16ºC) the UTAH model yields a large quantity of negative chill values in sub-tropical climates. Therefore, a modification of this model which does not consider the negative values for the chill accumulation, termed as model of Positive Chill Units (PCU) model was used (Linsley-Noakes *et al.*, 9). The trend analysis was done to analyse the variability and to calculate the sensitivity of the climatic factors. Significant effect of dependent variables on productivity was calculated using correlation analysis and step up regression (Draper and Smith, 6).

RESULTS AND DISCUSSION

Low temperature is indicative of the chilling hours experienced during winters. In the duration of 1985-2009, the rate of change of temperature per year was found to be 0.05°C. The data revealed the warming trends in the area. The maximum temperature varied between 23.8° to 26.5°C (Fig. 1). The annual average minimum temperature of Bajaura region showed decreasing trend at the rate of 0.02°C per year with an overall decrease of 0.5°C (Fig. 2). Mean temperature for the three seasons,

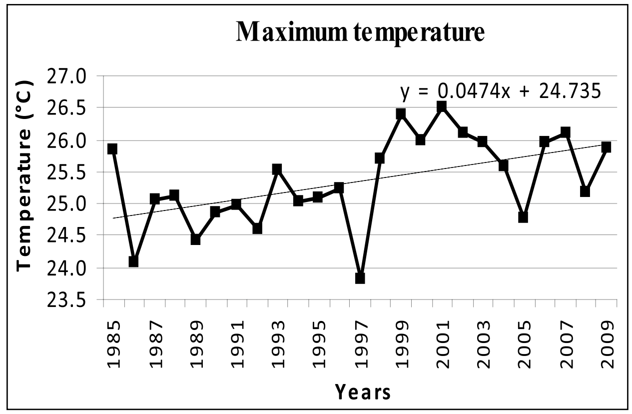

Fig. 1. Trends of maximum temperature in Kullu valley.

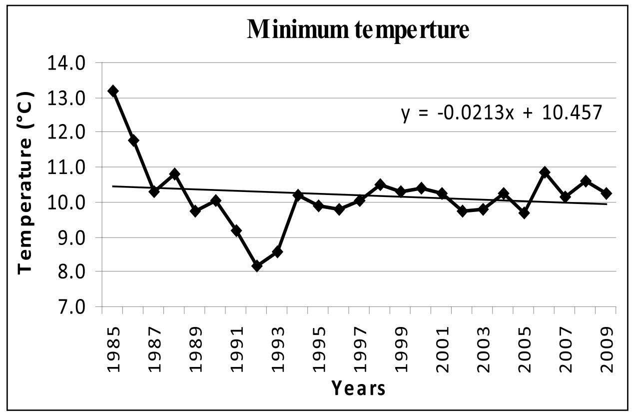

Fig. 2. Trends of minimum temperature in Kullu valley.

i.e., summer, spring and winter seasons showed a rising trend. Among three seasons, the temperature rise was found more pronounced in spring followed by winter and summer seasons. Winter temperature determines the apple productivity and is important for inducing dormancy, bud breaking and flowering (Jindal *et al.*, 8). Warm winters resulted in low chill accumulation, thus lowering the productivity. Wrege *et al.* (18) in their study also indicated that with the increment of few degrees rise in temperature there would be substantial decrease in the number of chilling hours, leading to a condition of practically not meeting enough chilling hours for growing temperate fruits. Similarly, the data for summer months, *viz.*, May and June showed an increase in temperature at the rate of 0.06°C per year, which influenced the size and quality of apples in lower Kullu valley (Fig. 3). The significant increase in temperature was recorded during the spring season with an overall increase of 2.4°C, followed by an increase of 2.3°C in winter and 1.4°C in summer season in the period of 1985-2009 (Fig. 3). Blanke and Kunz (3) examined the effects of climate change on pome fruits in Germany and also

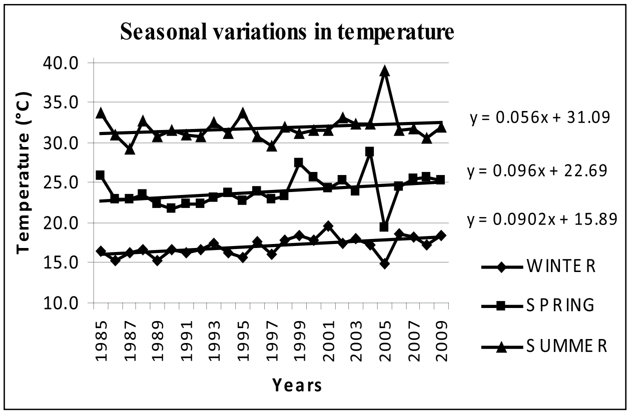

Fig. 3. Seasonal variations in temperature in Kullu valley.

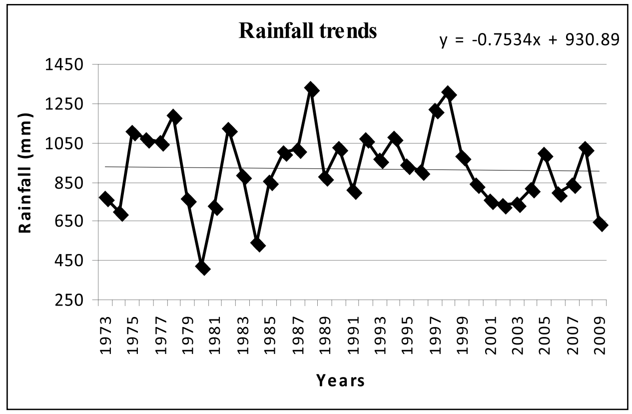

Fig. 5. Rainfall trends in Kullu valley.

concluded that temperature rise in winter was greater than in the summer season. The present study revealed significant increase (0.12°C) in maximum temperature and decrease (0.04°C) in minimum temperature per year in the month of March for the duration of 1985-2009 (Fig. 4). It was also observed that minimum temperature of March varied from 11.4 to 1.9°C leading to frost incidences, which adversely affected the flowering and fruit setting. Similarly, Blanke and Kunz (3) also concluded in their study that the more advanced flowering, brought about by warmer January to March temperatures coincided with late spring frosts, thereby maintaining the risk of yield loss due to spring frost in April. An overall decreasing trend over the years with erratic rainfall pattern in the Bajaura region of Kullu valley was obtained for the period of 1973-2009. The annual rainfall was found to be decreasing at the rate of 0.8 mm per year and an overall decrease of 27.1 mm in the 37 years (Fig. 5). Rains and snowfall during November, December and January are more beneficial in fulfilling chilling requirement of apple crop. Decreased rainfall in these months results in moisture stress. A decreasing trend was observed in all three months with much decrease in January (45.9 mm), which is detrimental month for good chill accumulation (Fig. 8) followed by December (11.7 mm) (Fig. 7) and November (10.4 mm) (Fig. 6).

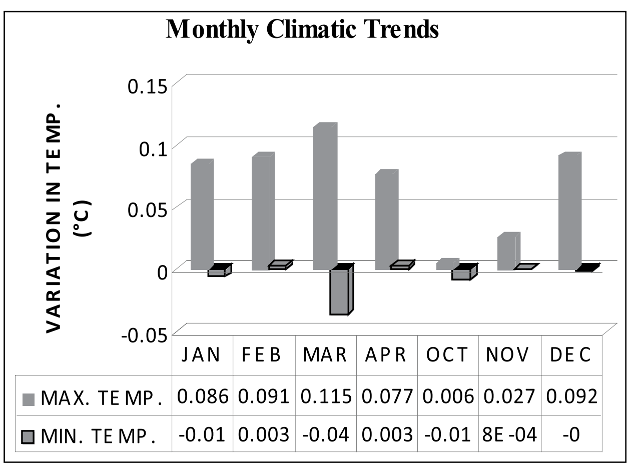

Fig. 4. Annual climatic trends in Kullu valley.

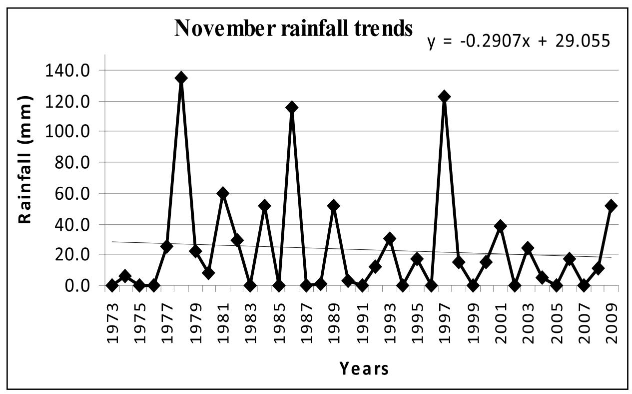

Fig. 6. November month rainfall trends in Kullu valley.

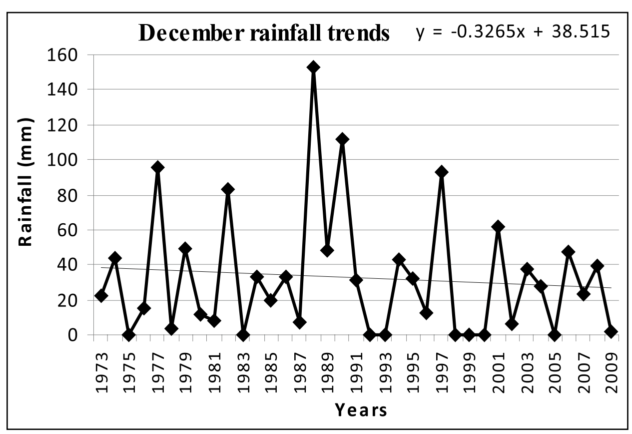

Fig. 7. December month rainfall trends in Kullu valley.

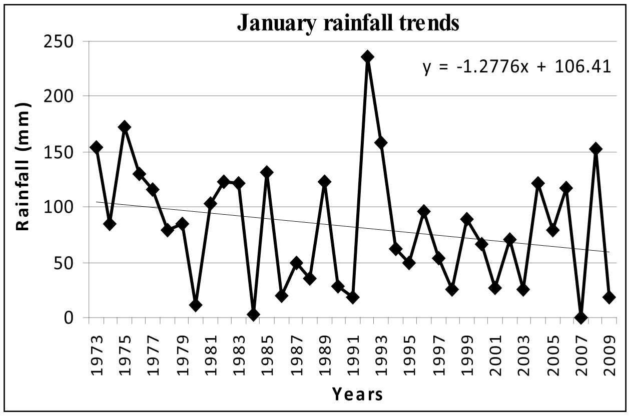

Fig. 8. January rainfall trends in Kullu valley.

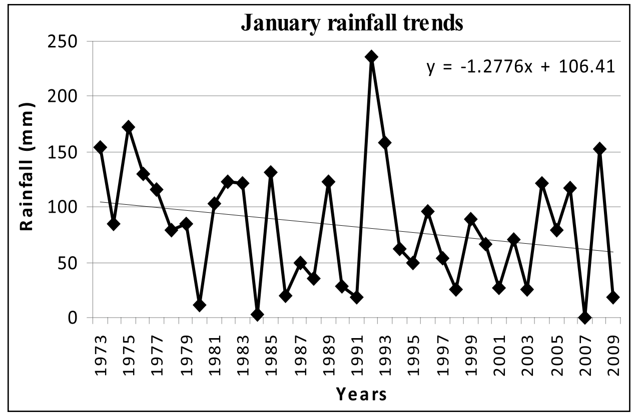

Fig. 10. Cumulative chill units trends at Kullu with Positive Chill Units using UTAH model.

As chilling hours for the period from November to February are important for bud breaking in apple, the cumulative chill units' requirement of apple for Kullu (Bajaura) region was determined by the UTAH model. The cumulative chill units showed an overall decreasing trend with an average decrease of 9.52 chill units per year with total decrease of 238.0 chill units over a period of 25 years (1985-2009) due to rise in temperature by 1.2°C during corresponding period in the Kullu region (Fig. 9). With the modification of UTAH model, *i.e.* Positive Chill Unit (PCU) model, the cumulative chill units of coldest months also showed decreasing trend of 6.5 chill units per year (Fig. 10) with total decrease of 162.5 chill units over a period of 25 years (1985-2009). There are average 127 chill units hours more observed in PCU model compared to Utah model considering negative chill units hours. In this case, upon applying the PCU model to the temperature regimes it was observed that the model effectively improved the quantity of accumulated chill units. The correlation between the productivity and the chill units was also found improved. Perez *et al.* (10) also observed that the application of Positive Chill Unit model in the sub-tropical zones of Chile improved the results obtained from the UTAH model. The decrease of chill units during November to February was observed due to the increase in surface air temperature at Kullu. Earlier, Rana *et al.* (11) also observed decline in chill units of coldest months due to increase in temperature affecting apple productivity of Kullu and Shimla regions.

The apple productivity in the study area decreased at the rate of 0.02 tonnes/ha per year (Fig. 11) with an overall decreases of 0.4 tonnes/ha productivity in the study period of 1985-2009. The rise in average temperature, long spells of drought during summers, less snowfall during winters over the period apple crop might have resulted in low production and poor quality of apple crop. Gautam *et al.* (7) also indicated inadequate winter chilling, occurrence of spring frosts, hails and droughts as key factors of climate change leading to poor fruit set thereby affecting productivity. The productivity sensitivity analysis with maximum temperature showed a negative rate of 3.89 every year (Fig. 12). This means that with increase in

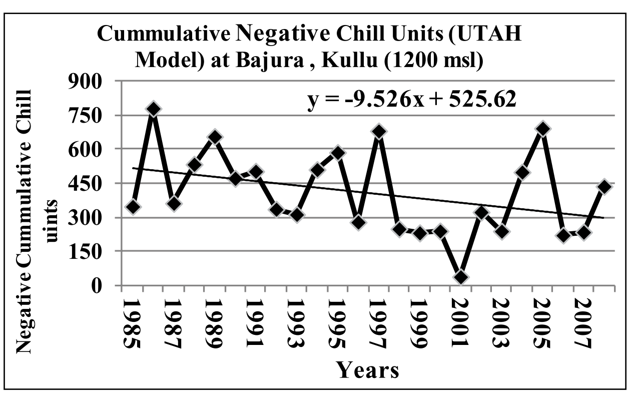

Fig. 9. Cumulative chill units trends at Kullu with Negative Chill unit UTAH model.

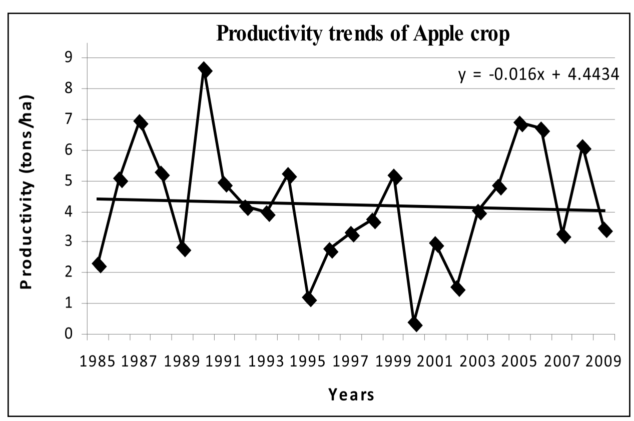

Fig. 11. Productivity trends of apple crop in Kullu valley.

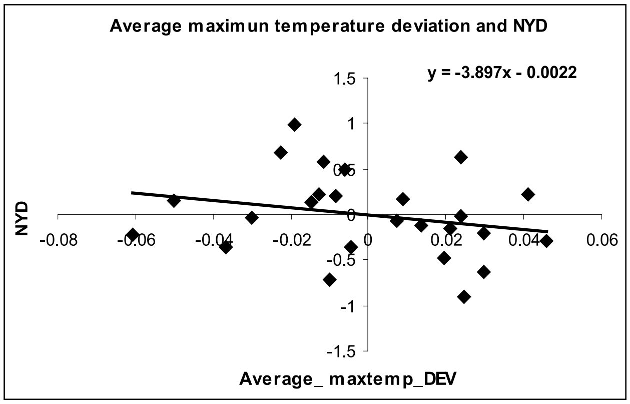

Fig. 12. Average maximum temperature deviation and NYD of apple.

maximum temperature, the yield decreases. Maximum temperature of November, minimum temperature of January, February, March, December and rainfall of January, February, March, October and December revealed positive sensitivity with the productivity. Maximum temperature of January, February, March, October, December, minimum temperature of October, November and rainfall November showed negative sensitivity. The weather during parameters (temperature and rainfall) of October, November and December months were found more sensitive to apple productivity (Table 1).

Correlations were worked out between different weather parameters and productivity, which revealed that maximum temperature for January, February, March, October, December, minimum temperature for October and November and rainfall of November had negative correlation, implying that increase in any of these parameters may cause reduction in the productivity. Similarly, maximum temperature of November, minimum temperature of January, February, March, October, December and rainfall for January, February, March, October, December showed positive correlation with productivity indicating an increase in productivity probably with improvement in these parameters. The productivity was regressed with rainfall, maximum and minimum temperatures to predict the productivity of apple crop.

$Y = 14.9342 + 0.251 (R_{12}) + 0.259 (MinT_2) - 0.36 (MinT_{11}) + 0.419 (MinT_1) - 0.36 (MaxT_3) - 0.24 (MaxT_{10})$ ($R^2 = 0.487$).

This equation can effectively predict yield up to 48.7 percent based on the weather parameters as the number of years available for the regression analysis were less than 30. The regression equation obtained was used to predict the yield for the duration of 1985-2009, which was then compared with the actual yield. The best fit year, *i.e.* 2002 was taken in which the predicted (1.6 tonnes/ha) and actual yield (1.53 tonnes/ha) showed the minimum difference. The year was used to predict the future productivity using the regression equation when the values of both maximum and minimum temperature were increased by 1°C and the rainfall was decreased by 10 percent. The result obtained showed a decrease in the productivity (*i.e.* from 1.6 to 1.2 tonnes/ ha). Thus, it can be said that if the temperature continues to increase coupled with a decrease in rainfall, the productivity will dwindle consequently. Therefore, revealing a significant role of these factors in predicting the productivity and indicating future climate changes are likely to cause decline in apple yields.

The farmers' perceptions revealed changes in climate to have adversely affected the apple cultivars. All farmers reported that change in the snowfall pattern led to a decrease in traditional (Royal, Red Delicious, Commercial, Laldevi, Kalidevi, Jonathan, Rich a Red etc.) and commercially important apple varieties. Majority of the farmers (90%) opined that apple cultivation has gone down while 63 percent have switched over to alternate crops (pears, kiwis, pomegranate, persimmon, cabbage and other vegetables) along with the apple crop. 100 percent people professed increase in low chill cultivars such as Gala, Spur, Vance, Vance Delicious, Spur Red, Oregon Spur etc. (Chauhan and Sharma, 5) and

Table 1. Sensitivity analysis of apple crop with climatic parameters.

Month	Max. temp.	Min. temp.	Rainfall
Average/total	y = -3.897x - 0.002	y = -0.069x - 0.002	y = 0.689x - 0.002
January	y = -0.244x - 0.002	y = 0.103x - 0.002	y = 0.006x - 0.002
February	y = -0.279x - 0.002	y = 0.437x - 0.001	y = 0.184x - 0.002
March	y = -0.751x - 0.002	y = 0.073x - 0.002	y = 0.063x - 0.002
October	y = -1.213x - 0.002	y = -0.377x - 0.002	y = 0.016x - 0.002
November	y = 0.142x - 0.002	y = -0.354x - 0.001	y = -0.044x - 0.002
December	y = -0.502x - 0.002	y = 0.038x - 0.002	y = 0.112x - 0.002

decrease in traditional Delicious varieties. 83 percent specifically in lower Kullu valley switched over to alternate sources of income. Whereas, 27 percent respondents felt that higher altitudes were getting more suitable for apple cultivation and hence, preferred to shift their orchards to the higher elevations, earlier unsuitable due to extremely low temperatures. Verma *et al.* (17) also reported from their farmer survey based study that increase in temperature particularly in areas above 2,500 m altitude has become suitable for apple cultivation, which was not possible two decade ago. Thus, indicating that higher altitudes, earlier unsuitable due to extreme cold conditions were now becoming suitable for apple cultivation. Biodiversity shift has also been reported by Sugiura and Yokozawa (16) predicting that the favourable regions to cultivate apples and Satsuma mandarins in Japan will gradually move northwards by 2060 due to the impact of global warming. 100 percent of the locals interviewed at Bajaura and nearby areas felt decrease in apple production with almost no orchard left productive up to commercial level. Majority respondents attributed the deforestation, population explosion and industrialization as major culprits for the climate change (Singh, 15). Strategic measures such as shift towards new varieties (low chill and high yielding varieties), change of choice of crops (vegetables and fruits), irrigation methods, rain water harvesting, shift of orchards to higher altitudes, bee keeping, more spray of chemicals, usage of composts, polyhouses, floriculture were adopted by 77 percent people to overcome adverse climatic effects (Table 2). It can be concluded from the study that temperature is the most predominant factor followed by rainfall governing apple productivity. The apple fruit setting and production was badly influenced by extremes in temperature. The results of the study revealed that increase in average temperature, prolonged droughts during summers, negligible or no snowfall during winters has rendered large area of lower Kullu valley unfit for apple cultivation. The farmers' perceptions revealed changes in the snowfall pattern which led to depletion and shifting of ecological niche of traditionally and commercially important apple varieties, increase in low chill cultivars and shift of apple towards higher altitudes. It was also observed that the climate variability (reduction in snowfall, change in temperature and rainfall pattern) has caused the loss of vigour, fruit bearing ability, reduction in size of apple fruit and increasing attacks of pests resulting in low production and poor crop quality.

Table 2. Farmers' perception of apple biodiversity shift.

Sl. No.	Particulars	Percent response
1.	Change in snowfall pattern	100
2.	Decrease in area under apple crop	90
3.	Change in apple traditional varieties	100
4.	Increase in number of apple low chill varieties	100
5.	Alternate source of income	83
6.	Decrease in apple production	100
7.	Shifting of orchard to higher altitude	27
8.	Stopped planting of apple crop	43
9.	Change in choice of crop	63
10.	Strategic measures adopted	77

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Received : June, 2013; Revised : September, 2014; Accepted : December, 2014