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Impact of changes in climatic conditions on temperate fruit production of Himachal Pradesh

RANBIR SINGH RANA, MANMOHAN SINGH*, RANU PATHANIA, S. K. UPADHYAY** and VAIBHAV KALIA

Centre for Geo- Informatics Research and Training, CSK HPKV, Palampur, India

**Meteorological Centre, IMD, Shimla, India*

***Department of Horticulture, CSKHPKV, Palampur, India*

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e mail : ranars66@rediffmail.com

सार – इस शोध पत्र में हिमाचल प्रदेश के सम-शीतोष्ण फलों जैसे:- आलूबुखारा, नाशपाती, आड़ू तथा खूबानी की उत्पादकता पर जलवायु परिवर्तन के प्रभावों का अध्ययन जलवायु सूचना एवं कृषकों की अवधारणा के आधार पर किया गया है। इसमें भिन्न-भिन्न ऊँचाईयों के तीन क्षेत्रों जैसे: शिमला, कुल्लू और पालमपुर का चयन किया गया है जिसका संबंध शीतोष्ण फलों की उत्पादकता एवं ठिठुरन भरी इकाईयों से है। हर क्षेत्र के जलवायु तत्व के वितरण के अध्ययन से पता चला है कि पिछले तीन से चार दशकों में शिमला, पालमपुर तथा कुल्लू के औसत तापमान में प्रतिवर्ष क्रमश: 0.050, 0.019 तथा 0.046 डिग्री सेल्सियस की वृद्धि हुई है। शरद ऋतु के दौरान होने वाली वर्षा की दर में प्रतिवर्ष शिमला में -9.86 मि. मी., कुल्लू में -11.1 मि. मी. तथा पालमपुर में -8.6 मि. मी. की गिरावट के कारण होने वाली ठिठुरन की मात्रा में कमी आई है। उताह मॉडल (UTAH Model) से ठिठुरन भरी इकाईयों की गणना करने से ज्ञात हुआ है कि पिछले 26 वर्षों की अवधि में शिमला जिला में प्रतिवर्ष दिसम्बर माह के दौरान 4.97 से अधिक ठिठुरन भरी इकाई, जनवरी माह में 0.64 इकाई और फरवरी माह में 3.75 इकाई की गिरावट देखी गई है। कुल्लू में प्रतिवर्ष दिसम्बर, जनवरी और फरवरी के महीनों में क्रमश: 1.73, 1.84 तथा 1.65 ठिठुरन भरी इकाईयों की गिरावट प्रेक्षित की गई है। पालमपुर में भी प्रतिवर्ष दिसम्बर से फरवरी तक के महीनों में ठिठुरन भरी इकाईयों में -2.8 से -12.8 इकाई की गिरावट पाई गई है। मान केण्डल की प्रवृति जाँच की विधि का उपयोग करते हुए ठिठुरन भरी इकाईयों के स्लोप की सार्थकता का पता लगाया गया है जिसमें यह पता चला है कि कुल्लू क्षेत्र में दिसम्बर माह में और शिमला क्षेत्र में जनवरी तथा फरवरी के महीनों में कोई महत्वपूर्ण प्रवृति नहीं रही है। ठिठुरन भरी इकाईयों में महत्वपूर्ण गिरावट कुल्लू में जनवरी से फरवरी माह में, शिमला में दिसम्बर माह में और पालमपुर में दिसम्बर से फरवरी तक के महीनों में देखी गई है। जलवायु परिवर्तन के संकेतों को कुल्लू, कांगड़ा तथा शिमला जिलों के कृषकों की अवधारणाओं से भी समर्थन मिला है। पिछले 20 से 30 वर्षों की अवधि में तापमान में वृद्धि होने से हिमपात में कमी आई है और इससे ठिठुरन संचयन प्रभावित हुआ है। पिछले ढाई दशकों में सम-शीतोष्ण फलों जैसे: नाशपाती, आड़ू, आलूबुखारा तथा खूबानी के उत्पादन में क्रमश: 0.172, 0.064, 0.018 तथा 0.018 टन प्रति हैक्टेयर प्रति वर्ष की दर से बढ़ोतरी पाई गई है। इस प्रकार हम देखते हैं कि तापमान में वृद्धि के कारण संचयी ठिठुरन में कमी होने की प्रवृति रही है और सभी स्थानों पर होने वाली वर्षा में कमी उप सम-शीतोष्ण जलवायु वाले मध्य पर्वतीय क्षेत्र से उच्च पर्वतीय क्षेत्र की शीतोष्ण जलवायु में अलग-अलग हुई है परन्तु इससे हिमाचल प्रदेश के सम-शीतोष्ण फलों की उत्पादकता पर कोई प्रभाव नहीं पड़ा है और इस जलवायु परिवर्तन से सेब के उत्पादन वाले क्षेत्र का आशाजनक रूप से पुन: स्थापन हुआ है।

ABSTRACT. The study examined the impacts of changing climate on productivity of temperate fruit crops *viz*., plum, pear, peach and apricot in Himachal Pradesh based on climate information and farmers' perception. Three study sites representing different elevations *viz*., Shimla, Kullu and Palampur were selected to relate the chill units with temperate fruit productivity. The climate element distribution over the period in each study site revealed an increase in the mean temperature to the tune of 0.050, 0.019 and 0.046 °C per year in Shimla, Palampur and Kullu respectively in the past 3 to 4 decade. The rate of decrease of rainfall per year during winter season was -9.86 mm in Shimla, -11.1 mm in Kullu and -8.6 mm in Palampur leading to a decrease in chill accrual. The chill units calculated using the UTAH model showed a decline of more than 4.97 chill units per year during December month, 0.64 units per year in January and 3.75 units per year in February month in past 26 year period in Shimla district. The decrease of 1.73, 1.84 and 1.65 chill units every year during December, January and February months were observed at Kullu. The decrease of chill units during December to February ranged from -2.8 to -12.8 per year in Palampur were also observed. The significance of the slope of chill units was worked out using Mann-Kendall trend test which indicated no significant trend for the December month for Kullu region and January and February months at Shimla. Significant decreasing trends in chill units for January to February months for Kullu, December month for Shimla and December to February months were observed at Palampur. The indications of changes in climate have also been supported by the farmers' perception in Kullu, Kangra and Shimla districts accounting a

reduction in snowfall with an increase in temperature in past 20 to 30 years affecting the chill accumulation. The temperate fruits pear, peach, plum and apricot showed significant increase in the production at the rate of 0.172, 0.064, 0.018 and 0.018 t/ha per year during the past two and half decade respectively. Thus, the decreasing trends in cumulative chill units due to increase in temperature and reduction in rainfall in all locations varied from sub temperate climate in mid hills to temperate in high hills did not affect the productivity of temperate fruits in Himachal Pradesh and a promising replacement for apple shifting region in the face of climate change.

Key words – Temperate fruits, Chill unit requirement, Snowfall, Farmers' perception, Climate change.

1. Introduction

Climate change is the major concern today with serious implications for natural ecosystems, global atmospheric circulation, hydrological cycle, and agriculture to a larger extent. The rates of warming in the Hindu Kush Himalaya (HKH) region are significantly higher than global mean warming of 0.74 °C over the last 100 years and warming rates are much higher in the high-altitude regions than in the low-altitude regions. Mountainous environments are considered sensitive indicators of climate change (IPCC, 2007). The mountain ecosystems are particularly vulnerable to climate change due to dependence of the people on natural resources for their livelihood, comparatively higher exposure to extreme events and widespread poverty and marginalization (Partap and Partap, 2002). The long term temperature trends have revealed an increase in annual maximum temperature in Himachal Pradesh where the rate of change is +0.06 °C per year. The increase in maximum temperature was also evident during the monsoon season. However, the minimum temperature trends are inconsistent. The rainfall trends during the annual monsoon and post monsoon seasons have shown decreasing trends for the duration of 1991-2010. Whereas the summer rains have shown increasing trends (Rathore *et al*., 2013). A wide range of mountainous agro climatic conditions serve as rich repositories of large number of horticultural commodities like fruit crops (Sub tropical to temperate), flowers, vegetables, mushrooms, hops, tea, medicinal and aromatic plants. Agriculture, horticulture and animal husbandry are mainstay of the majority of the population in the mountainous state of Himachal Pradesh despite very small irrigated area. The horticultural crops occupy 23 per cent area of total cultivated area of the state (Anonymous, 2015). The contribution of horticulture sector is about 7 per cent towards GSDP out of about 15 per cent by entire agriculture and allied sectors constituting 48 per cent (Anonymous, 2013). The significant contribution is towards employment generation growth as a percentage of all agricultural employment in HP increased from 0.9 per cent to 28 per cent between 1983 and 2009 -10 (Kumar *et al.*, 2011).

In Himachal Pradesh, the stone fruits like peach, plum and apricot can be grown at an elevation ranging from 800 to 1500 m amsl with an annual rainfall of 90-100 cm while pear is commercially grown at elevation between 1500-2700 m amsl with annual rainfall of 25-40 cm. Due to sharp variations in the altitude even a very small change in any climatic parameter can affect land utilization and cropping pattern. In the past few decades, the mountain areas of the state have been severely affected by global climate change. The different development phases like vegetative growth, flowering and fruit development of stone fruits especially peach, plum and apricot have been influenced by climatic vagaries (Thakur *et al*., 2010). Low temperature and frost conditions during fruit maturity period cause sub lethal injury or shriveling of fruits thus causing heavy loss to the crop load (More and Bhargava, 2010). Thus the effects of the elevated temperature, unpredictable and irregular precipitation can disrupt the normal growth and development of plant that ultimately affect the crop production.

The present study aims to examine the impact of climate change *vis-à-vis* production of stone fruit crops grown of Himachal Pradesh through the analysis of production and chill unit requirement. The information obtained would provide a better understanding of chilling requirement of stone fruit crops and the relation of chill requirement with the production of stone fruits based on climate information and farmers' perception.

2. Data and methodology

2.1. *Study sites*

Three study sites representing different elevations *viz*., Kullu, Shimla and Palampur in Himachal Pradesh were selected to examine the perceptions of farmers for climate change and to relate the chill units with temperate fruit crops in the face of climate change. The study site of Kullu district represents 1200-2500 m above mean sea level. This elevation zone represents mid hill to high hills and receives snowfall in high hills during winter months. The region represents 16.04% of the total geographical area of Himachal Pradesh. The ambient temperature ranges between 7.9 °C and 25.6 °C. The elevation above 2200-3250 m amsl was represented by the second study site of district Shimla represents 8.8% of the total geographical area of the state. The area is having mid hills to high hills. Mean annual temperature of the region is 15.4 °C. The third study site of Palampur located in district Kangra represents 700-1500 m amsl. This study site represents 8.4% of total geographical area of the state.

The average temperature is highest during May (31 °C) and lowest during February (4.9 °C).

2.2. *Socioeconomic survey*

The socioeconomic surveys were conducted in Kullu, Shimla and Palampur regions of Himachal Pradesh to examine how farmers in Himachal Pradesh perceive climate change. Weather data from 1969-2015 was used to measure the accuracy of perceptions of the farmers. Perception of climate change was structured for three valleys (Kullu, Shimla and Palam) with multistage stratified sampling technique by knowledge of crop climate interaction. Local perception of the climate variables to temperate fruit production were noticed from forty farmers from each region (19 marginal, 16 small and 5 large farmers from Kullu, whereas, 4 marginal, 9 small and 27 large from Shimla and 15 small, 20 marginal and 5 large in Palampur) to discern farmers' perceptions regarding climate change. Perceptions were made on the basis of gathered data of snowfall, temperature and rainfall for two periods, *viz.*, period-I (2005-06) and period-II (1995-96).

2.3. *Chill units calculation*

The Cumulative chill units' requirements of temperate fruit crops for Kullu, Shimla and Palampur were calculated using UTAH model which assigned chill unit values to different temperature ranges (Byrne and Bacon, 1992). UTAH model also introduces the concept of relative chilling effectiveness and negative chilling accumulation (or chilling negation) as follows:

1 hour below 34 °F	=	0.0 chill unit
1 hour 37-48 °F	=	1.0 chill units
1 hour 55-60 °F	=	0.0 chill units
1 hour >65 °F	=	-1.0 chill units
1 hour 35-36 °F	=	0.5 chill units
1 hour 49-54 °F	=	0.5 chill units
1 hour 61-65 °F	=	-0.5 chill units

2.4. *Mann Kendall test trends analysis of chill units & stone fruits production in Himachal Pradesh*

The trends of chill units and temperate fruits production (pear, plum, peach and apricot) for past two to three decades in temperate fruit growing areas and total productions of Himachal Pradesh were analyzed using non-parametric Mann-Kendall trend test (Mann (1945); Kendall (1975)) to verify the statistical significance of trends. According to this test, the null hypothesis H_0 assumes that there is no trend (the data is independent and randomly ordered) and this is tested against the alternative hypothesis H_1, which assumes that there is a trend.

The test statistic *S* is:

$$S = \sum_{i=1}^{n-1}\left[\sum_{j=i+1}^{n} \operatorname{sgn}\left(R_j - R_i\right)\right]$$

A positive (negative) value of *S* indicates an upward (downward) trend. If the null hypothesis H_o is true, the statistic *S* is approximately normally distributed with the mean and variance (σ^2) as follows:

$$\mu = 0$$

$$\sigma^2 = \frac{n(n-1)(2n+5) - \sum t_j(i)(i-1)(2_i+5)}{18}$$

The test statistic Zs is used a measure of significance of trend. In fact, this test statistic is used to test the null hypothesis, H_0. If |Zs| is greater than $Z_{\alpha/2}$, where α represents the chosen significance level then the null hypothesis is invalid implying that the trend is significant, while accepting H_0 indicates no trend was detected.

The trends of production of pear, plum, peach and apricot were worked out for different regions to examine the change in production of these crops at different elevations.

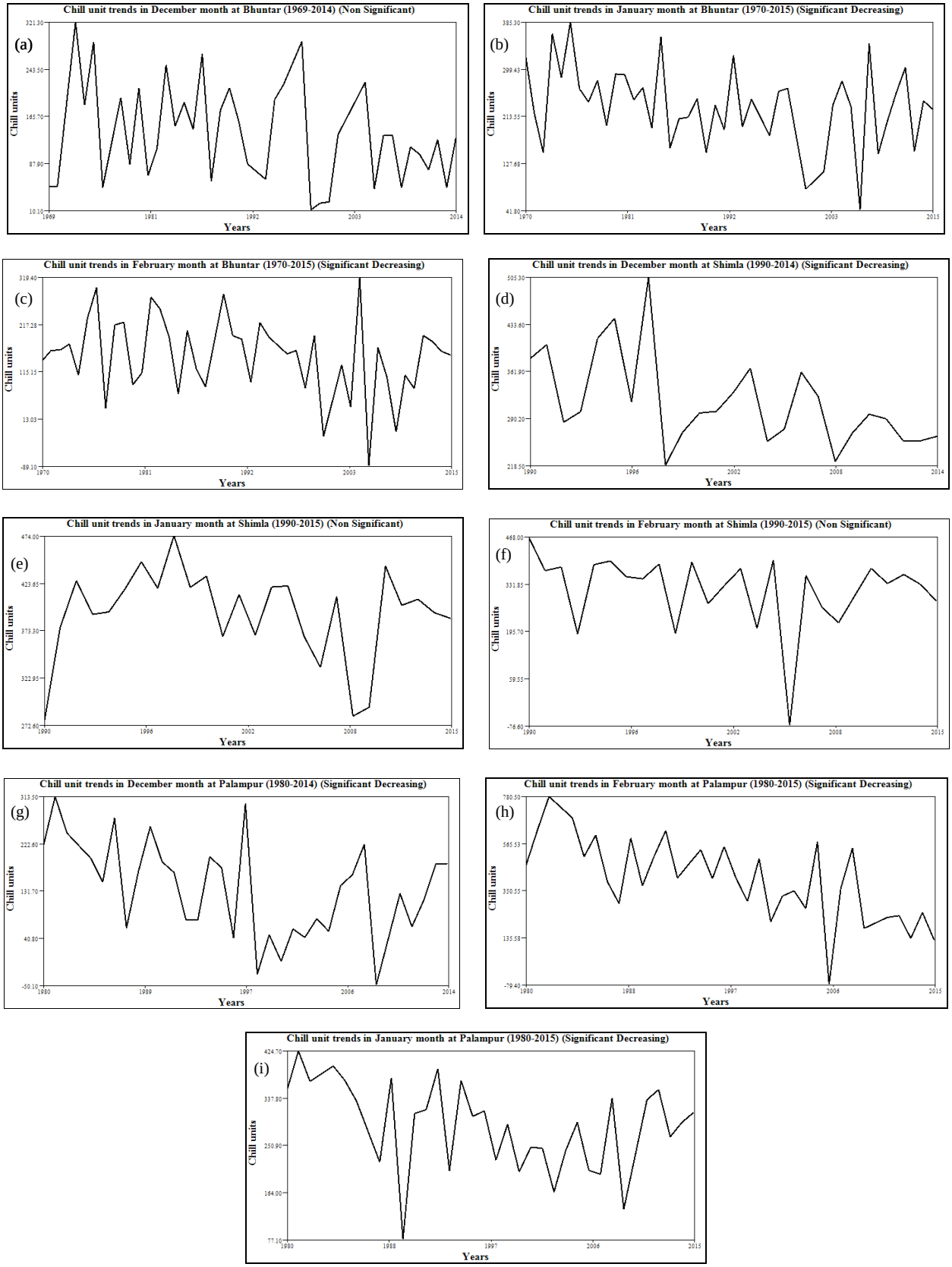
2.5. *Correlation studies*

Correlation between the stone fruits production and chill units requirement at the three study sites was also worked out using the standard procedure.

3. Results and discussion

3.1. *Climatic elements distribution in temperate fruit growing regions*

(a) *Kullu region*: This region is known as the bowl of off season vegetable of Himachal Pradesh. The apple crop particularly in higher hills followed by other temperate crops like pear, peach, apricot and plum dominates in this region. The perusal of climatic data indicated that the ambient temperature of this region ranged between 9.1 °C to 36.7 °C around the years. Temperature during *rabi* season hovers around 16.3 °C whereas during *kharif* season average mean temperature remained below 32.2 °C. Mean annual temperature in Kullu Valley showed an increase of 0.046 °C/year in last four decades. During *rabi* season temperature showed increase in temperature to the tune of 0.079 °C. Among months, June to September, temperature showed decreasing trends. Rainfall in the region showed an exceptional decrease of



Figs. 1(a-i). Chill unit trends of December-February month at three study sites (Bhunter, Shimla and Palampur)

TABLE 1

Farmers' perception regarding climate change (Percent multiple response)

Particulars	Shimla region	Kullu valley	Palam valley
Increasing temperature during summer	80	85	90
Prolonged summer season	48	66	62
Short summer season	8	10	5
Delay in the onset of rainy season	80	85	88
Uneven distribution of rainfall	96	88	98
Insufficient rainfall during rainy season	72	77	95
Delay in the onset of winter season	48	68	45
Very low temperature in winter season	12	-	10
Short winter period	88	94	88
Temperature above normal during winter	88	92	96
Reducing snowfall in winter	100	100	-
High humid weather	36	40	75
Increasing foggy days in winter	52	16	22
Increasing cloudy days in winter	18	16	15
Unpredictable rainfall	52	76	65
Threats of flood	50	88	-
High velocity winds	-	-	20
Mud slides	-	-	-
High intensity of rainfall	-	20	-

TABLE 2

Cumulative chill unit trends (Mean monthly model) equations for different months at Kullu, Shimla and Palam valley

Months	Kullu valley	Slope	Shimla region	Slope	Palam valley	Slope
January	$Y = -1.84\ x + 273.7$	-1.84	$Y = -0.64\ x + 399.3$	-0.64	$Y = -2.81\ x + 335.4$	-2.81
February	$Y = -1.65\ x + 186.4$	-1.65	$Y = -3.75\ x + 364.9$	-3.75	$Y = -12.79\ x + 626.9$	-12.79
December	$Y = -1.77\ x + 174.5$	-1.73	$Y = -4.97\ x + 380.0$	-4.97	$Y = -4.29\ x + 207.0$	-4.29

9.5 mm/year over the years. *Rabi*/winter season showed decrease in rainfall to the tune of 11.1 mm/year, conversely *kharif* season showed increase.

(b) *Shimla region*: The average annual rainfall of the region varies between 951 mm to 1782 mm annual from South to North over the years. The average mean temperature of the region touched a minimum of 7.6 °C whereas maximum temperature went up to 20.3 °C during May and July month. The maximum and minimum temperature showed increase to the tune of 0.08 °C and 0.061 °C/year respectively during *rabi* season**.** Mean temperature showed increase of 0.04 °C/year annually. Rainfall showed decreasing trend during *rabi* season by 9.86 mm and 1.65 mm per year during *kharif* season.

(c) *Palampur*: Long term monthly averages of rainfall and temperatures for Palampur (1974-2013) indicated a mean annual rainfall of 2300.6 mm, out of which 76.8% was received during South Western-monsoon (June-September), 4.3% in North Eastern-monsoon season (October-December), 8.6% in winter season (January-February) and 10.3% in summer season (March-May). Climatologically, *rabi* season was more vulnerable than *kharif* season. The monthly average rainfall registered a decrease in rainfall during all the months except October. Past 31 years database revealed a reduction in rainfall during *rabi* season to the tune of 14.8 mm (Rana *et al*., 2011).

The mean surface air temperature indicated significant warming during February to April in all the three locations thus inducing profuse flowering and subsequently the fruit set. Also the decrease trends of rainfall to the tune of 1.4 mm per year during these months from the average of 86.5 mm were observed. These findings regarding vagaries of weather have also been supported by the socio-economic survey conducted in these regions.

3.2. *Farmers' perception*

The socio-economic surveys were conducted in Kullu, Shimla and Palampur of Himachal Pradesh and

TABLE 3
Results of Mann-Kendall test for cumulative chill units for different months at Kullu, Shimla and Palam valley and productivity of stone fruits

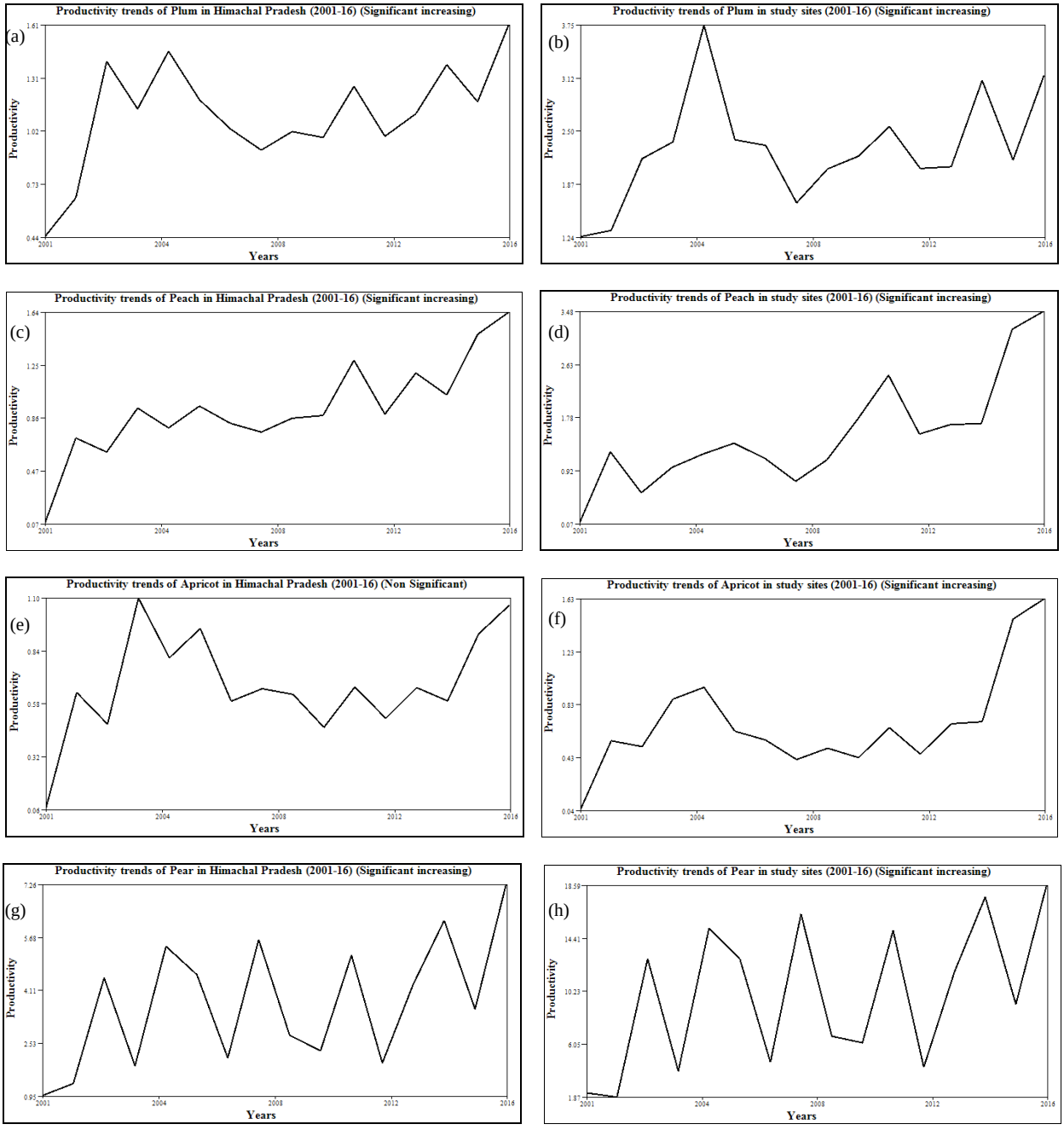
Study site , chill units month, productivity & stone fruit		Mann-Kendall Statistic (S)	Standard Deviation	Z statistic (Z_S)	Trend
Chill units Bhuntar (Kullu)	December	-147	105.6	1.382	Non-significant
	January	-229	105.6	2.159	Significant, Decreasing
	February	-191	105.6	1.799	Significant, Decreasing
Chill units Shimla (Shimla)	December	-108	42.81	2.499	Significant, Decreasing
	January	-35	45.36	0.749	Non-significant
	February	-69	45.36	1.499	Non-significant
Chill units Palam (Kangra)	December	-175	70.41	2.471	Significant, Decreasing
	January	-190	73.41	2.574	Significant, Decreasing
	February	-340	73.41	4.617	Significant, Decreasing
Productivity	Plum (H.P)	32	22.2	1.396	Significant, Increasing
	Plum (Study sites)	34	22.2	1.486	Significant, Increasing
	Peach (H.P)	84	22.2	3.737	Significant, Increasing
	Peach (Study sites)	78	22.2	3.467	Significant, Increasing
	Apricot (H.P)	22	22.2	0.945	Non-significant
	Apricot (Study sites)	42	22.2	1.846	Significant, Increasing
	Pear (H.P)	48	22.2	2.116	Significant, Increasing
	Pear (Study sites)	46	22.2	2.026	Significant, Increasing

summarized perceptions of the farmers with regard to changing climate in Himachal Pradesh (Table 1). Farmers to the tune of 100 per cent at Kullu and Shimla districts of Himachal Pradesh perceived a definite reduction in snowfall overtime during winter season. Reduction in the intensity of snowfall and changes in timing of snowfall are thought to be two important ways as to oscillate snowfall events. According to farmers, late snowfall in February and March occurs mostly as a mixture of sleet and rain, resulting in lower temperatures and thereby a late onset of spring. There was a perception that the temperature distribution has undergone a significant shift in addition to an overall increase in temperature. 85 per cent farmers of Kullu, 80 per cent of Shimla and 90 per cent farmers of Palampur noticed an increase in temperatures. 88 per cent farmers of Kullu, 96 per cent farmers of Shimla valley and 98 per cent farmer's of Palampur reported uneven and insufficient distribution of rainfall during rainy season. The farmers also opinioned that winter period has shortened and there is delay in onset of winter season. The other signs of climate change which were reported by the farmer's were prolonged summer season, delay in the onset of winter season with short winter period, decrease in snowfall in high hills, delay in the onset of rainy season, insufficient and unpredictable rainfall imposing a stress on ecological and socioeconomic systems.

3.3. *Cumulative chilling units' trends*

In the present study, the trend analysis of chill units was done with Mann-Kendall trend test for the pre bloom period (December to February) essential for chill accumulation. The z-statistics for Bhuntar region showed no significant trend for the December month with Mann-Kendall trend test. However, a significant decreasing trend was observed in the chill units' accumulation during the January to February months at Bhuntar site for Kullu district [Figs. 1(a-c)]. A significant decreasing trend was observed in the chill units for the month of December month for the Shimla site. The January and February month however, revealed a non-significant trend in the chill units at Shimla [Figs. 1(d-f)]. The non parametric Mann-Kendall trend test analysis indicated significant decrease in average chill units during December to February month in the Palampur of Kangra district (Table 3). The determination of the trend and z-statistics revealed significant decreasing trend in chill units during December to February month [Figs. 1(g-i)].

The data on cumulative chill units of Shimla and Palampur also showed a decline of 3.75 and 12.79 units per year respectively during the month of February. In Shimla, the cumulative chill units showed a decline of 0.64 and 3.75 units per year during January and February months, respectively. In Palampur, the cumulative chill units during January were 2.81 and 4.29 units per year in December. In Kullu valley, the cumulative chill units showed a decline of 1.84, 1.65, 1.73 units per year during January, February and December months, respectively (Table 2). Vedwan and Robert (2001) also concluded that in Kullu district the lack of early cold during December and January adversely affected the chill unit hours' accumulation. Similarly, Rana *et al.* (2011) and Verma *et al.* (2006) also reported decrease in chill units' hours in the apple growing areas of Himachal Pradesh.



Figs. 2(a-h). Productivity trends of Plum, Peach, Apricot and Pear in Himachal Pradesh and study sites (Shimla, Kullu and Kangra)

3.4. *Production of temperate fruits in Himachal Pradesh*

The temperate fruits like pear, peach, plum and apricot showed increase in the production at the rate of 0.172, 0.064, 0.018 and 0.018 t/ha per year during the last ten years. The Mann-Kendall trend test analysis revealed a significant increasing trend (Table 3) in the production of pear, peach, plum and apricot in the study sites and state thereby exhibiting that the decreasing trends of chill units' hours did not influence the production of these fruit crops to a much extent [Figs. 2(a-h)]. The decrease in chill units affects the temperate fruits such as apple growing on higher altitudes with higher chill requirement (Rana *et al.*, 2011). The preferred range of weather parameters for apple cultivation is now shifting towards higher altitudinal regions such as Kinnaur where changes in climate are becoming favorable for apple growing.

Verma *et al.* (2006) also evaluated the chill units and production relationship for the Kinnaur district and found that the region was becoming more suitable for apple cultivation owing to the increasing trend in temperature. Rai *et al*. (2015) mentioned that chill unit hour's requirement for peach, pear, plum and apricot were 200 to 1200 hours compared to 1000 to 1500 hours for apple. The farmers' perception also revealed decrease of 18.2 and 3.3 per cent per farmer area under apple in Kullu and Theog valley respectively.

4. Conclusions

During past three to four decades, the cumulative chill units showed a decrease in different study sites representing different elevations with sub temperate in mid hills to temperate climate in high hills in Himachal Pradesh. The reductions in cumulative chill units during winter months ascribed due to increase in temperature and reduction in rainfall. However, the productivity of the temperate fruits *viz*., pear, peach, plum and apricot corresponding to study sites and state productivity showed significant increase due to large range of cultivars having low cumulative chilling units requirements compared to apple. Thus, the decreasing trends in cumulative chill units due to increase in temperature and reduction of rainfall in the locations having sub temperate in mid hills to temperate climate in high hills proved to be positively benefited temperate fruits in Himachal Pradesh which is a promising adaptation for apple shifting region in the face of climate change.

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