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Short communication

Climatic variability during different phenophases and its impact on temperate fruit crops

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Evidences of climate change are being witnessed worldwide and Himalayas are no exception. Anthropogenic activities are acting as a precursor for enhanced greenhouse effect in the mighty Himalayas, thus exposing them to climate vagaries. Temperature and precipitation variations in the north-west Himalaya were reported by Bhutiyani *et al*. (2009). During last century, temperature in the north-west Himalayas has increased by 1.6 °C, which is higher than the global figure of 0.85 °C (IPCC, 2014). Any deviation of external optimal conditions in terms of rainfall and temperature affect the fruit plants (fruit bearing ability, vigour, quality and intensity of diseases and pests) through changes in mechanical and physiological activities (Bal and Minhas, 2017). For many fruit and nut species of the temperate and subtropical climates fulfilment of cultivar-specific chilling requirements is a prerequisite for producing economically satisfactory yields (Leudeling *et al*., 2015). There is very little evidence of impact of climate variability during phenophases on temperate fruit crops. Therefore, study was conceptualized to quantify the change in climatic variables during pre-flowering, flowering and fruit and development stages in Kullu district from 1990 to 2016 and to assess the impact of such changes on fruit productivity.

Studies were conducted in Kullu district located in mid hill to high hill wet temperate zone (30° 22' 40" N to 33° 12' 40" N latitude and 75°45'55" E to 79° 04' 20" E longitude) of Himachal Pradesh which is known for its contribution in horticulture sector (Map 1). Mean minimum, maximum, diurnal temperature and rainfall data of Kullu district was collected since 1990 to 2016 from India Meteorological Department (IMD), Shimla. Climatic parameters were arranged into pre flowering, flowering, and fruit setting and development stages from November to February, March to April and May to August respectively, depending upon various phenophases of the temperate fruit crops and seasonal trends were analyzed. Area and production data of apple, pear, plum, peach, apricot, cherry, pomegranate, walnut and almond crops was collected from Directorate of Horticulture, Shimla from 1990 to 2016 and productivity was worked out. Trend analysis was done by using Mann-Kendall test which was quantified by

Table 1: Climatic trends and Sen's slope during different phenophases

	Mean	Sen's slope	p-value
Pre Flowering (November-Feb)			
Average max temp	18.81	+ 0.04	0.04
Average min. temp	3.10	+ 0.01	0.52
Total rainfall	216.4	- 2.58	0.20
Diurnal temp	15.7	+ 15.69	0.19
Flowering (March-April)			
Average max. temp	24.7	+ 0.12	0.01
Average min. temp	8.3	+ 0.04	0.00
Total rainfall	176.6	-6.17	0.00
Diurnal temp	16.5	+ 0.07	0.06
Fruit-setting (May-August)			
Average max. temp	31.50	+ 0.03	0.23
Average min. temp	17.7	+ 0.02	0.29
Total rainfall	360.3	+ 0.98	0.76
Diurnal temp	13.8	+ 0.01	0.76

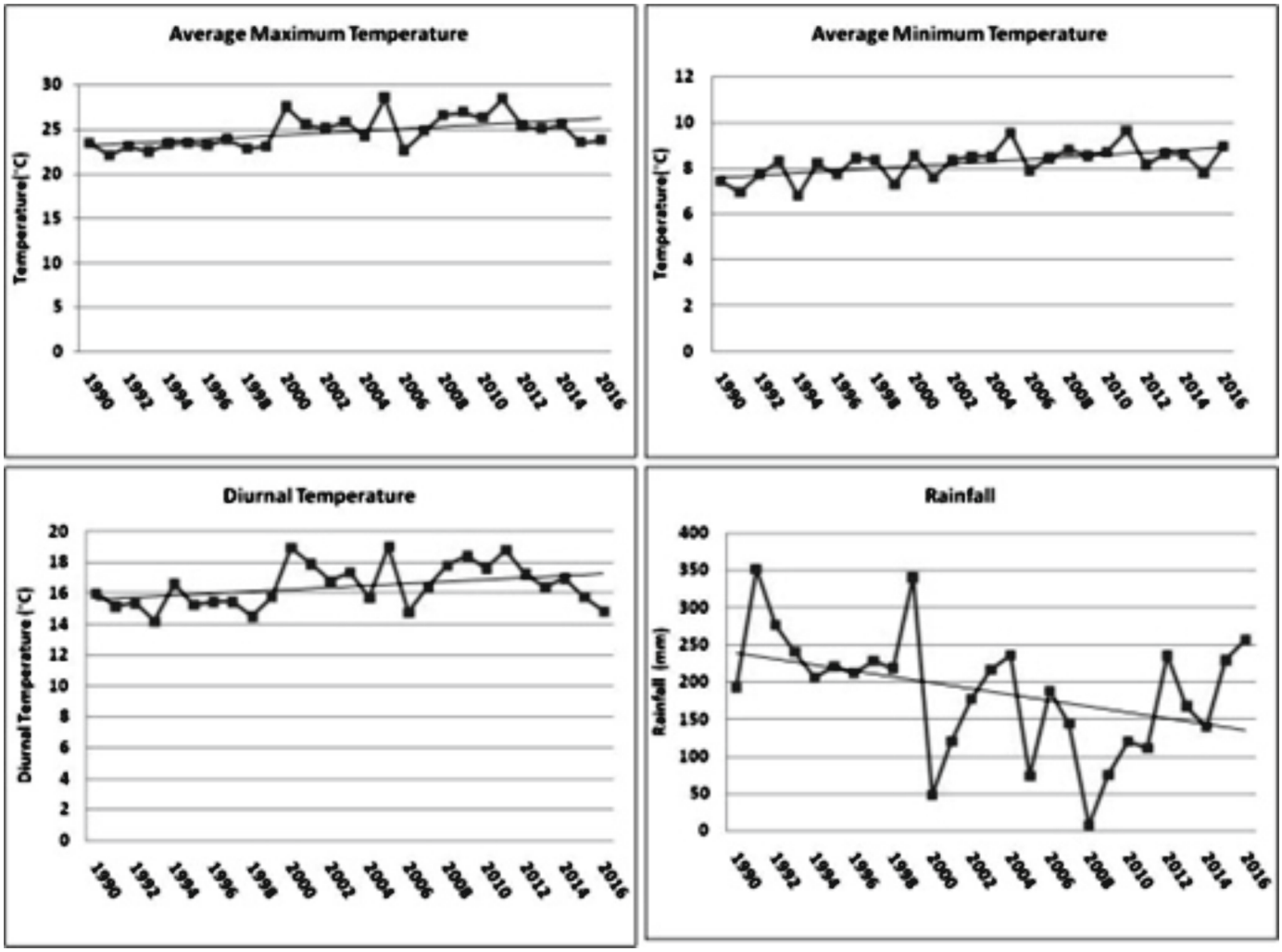

Fig. 1: Variability trends of average maximum, minimum, diurnal temperature and rainfall from 1990 to 2016 during flowering phase

Sen's slope method (Sen, 1968; Chakraborty *et al.,* 2017; Waghaye *et al.,* 2018). Standardized temperature and precipitation indices were also computed (Koundahe *et al.,* 2017). Pearson's correlation coefficient and multivariate regression analysis were performed to confirm the contribution of anomalies of climatic parameters on fruit crop productivity (Vaidya *et al.,* 2018).

A highly significant change in climatic variables was observed during flowering season in comparison to pre flowering and fruit setting season (Table 1; Fig. 1). During flowering period, average maximum temperature showed a noteworthy increasing trend of 0.12 °C per year while a rise of 0.04 °C per year was recorded in minimum temperature from 1990 to 2016. Total rainfall significantly decreased by 6.17 mm per year during flowering season. During pre-flowering season average maximum temperature significantly increased by 0.04 °C year^{-1}.

Standardized Anomaly Index of climate variables for different phenophases is depicted in Table 2. Mean maximum temperature during flowering phase remained above long term average values from 2000 to 2016 indicating a warming trend (Fig. 2). Minimum temperature during flowering period exhibited a significant warming trend from 2002 to 2016 (Fig. 2). Rise in temperature of Himalayas was also observed by Shekhar *et al.* (2010).

The productivity trends of temperate fruits did not show any significant change over last 27 years except pear, peach and apricot crops (Table 3). Highest increase was observed in pear (1.09 t ha^{-1}yr^{-1}) followed by peach (0.04 tha^{-1}yr^{-1}) and apricot (0.01 t ha^{-1}yr^{-1}). The almond crop, however recorded decrease in productivity by 0.005 t ha^{-1}yr^{-1}.

During flowering period apple productivity was found to be positively correlated with the minimum temperature (0.35). Warmer weather during spring is beneficial to pollination and fruit set, thus favours the ultimate production (Caprio and Quamme, 2005). Plum was most affected by

Table 2: Trends of SAI for average maximum, minimum, diurnal temperature and rainfall from 1990 to 2016

	Mean	Sen's slope	p-value
Pre Flowering (Nov-Feb)			
Average max temp	18.8	+ 0.04	0.04
Average min. temp	3.1	+ 0.01	0.54
Total rainfall	216.4	-3.00	0.96
Diurnal temp	15.7	+ 0.03	0.19
Flowering (Mar-Apr)			
Average max. temp	24.7	+ 0.07	0.00
Average min. temp	8.3	+ 0.06	0.00
Total rainfall	176.6	-0.006	0.07
Diurnal temp	16.5	+ 0.01	0.76
Fruit setting (May-Aug)			
Average max. temp	31.5	+ 0.04	0.24
Average min. temp	17.7	+ 0.03	0.30
Total rainfall	360.3	+ 0.03	0.20
Diurnal temp	13.8	+ 0.01	0.76

Table 3: Crop productivity trends with Sen's slope value

Fruits Productivity	Mean	Sen's slope	p-value
Apple	4.03	+ 0.06	0.38
Pear	16.78	+ 1.09	0.00
Plum	3.69	+ 0.04	0.28
Peach	1.05	+ 0.04	0.00
Apricot	0.30	+ 0.01	0.00
Cherry	0.51	-0.006	0.18
Pomegranate	1.06	+ 0.0005	0.95
Walnut	0.60	0.00	0.65
Almond	0.12	-0.005	0.00

maximum, diurnal temperature and rainfall during flowering period. Highly significant correlation coefficient values during pre-flowering stages indicate the impact of climatic fluctuations on the productivity of apple, pear and almond crops. Productivity of apple and pear exhibited a strong negative correlation with maximum temperature (-0.47 and -0.40) during pre-flowering period depicting that increase in maximum temperature reduces the productivity of these crops (Table 4). Productivity of almond was negatively correlated with maximum temperature (-0.34). Cherry productivity was positively correlated with minimum temperature (0.33). Similar results were also obtained by Tromp and Borsboom, (1994) and Sharma *et al*., (2013) who observed significant negative correlation between maximum temperature and productivity of apple in Shimla.

Contribution of climatic variables to productivity fluctuation was observed highest during the pre-flowering season. In pear, apple, cherry, almond and plum 34.5, 29.5, 19.1, 19.1 and 18.9% productivity fluctuations are due to climatic variables, while 65.5, 70.5, 80.9, 80.9 and 81.1% changes are due to high quality planting material and better orchard management practices (Table 4). Similarly, climatic fluctuations in flowering, and fruit setting and development changes are altering the productivity by 1.5% in walnut to 18.5% in apple and 0.9% in plum to 26.2% in almond respectively. Among all the crops apple was comparatively highly affected by climatic variables during all three stages (29.5, 18.5 and 16.6%) followed by plum (34.5, 8.5 and 5.0%), apricot (2.4, 12.2 and 19.1%), cherry (19.1, 14.6, 4.3%) and almond (19.1, 8.3 and 26.2%).

Higher maximum temperature and rainfall variability was observed during flowering period. During flowering period minimum and maximum temperature has increased by 0.04, 0.12°C per year and rainfall decreased by 6.17 mm per year, respectively, during last 26 years. Higher anomalies in maximum and minimum temperature were reported during all

Table 4: Correlation and multivariate regression analysis of detrended fruit productivity

S No.			Pre flowering season					Flowering season					Fruit setting and development				
			Min T	Max T	DT	RF	R^2	Min T	Max T	DT	RF	R^2	Min T	Max T	DT	RF	R^2
1.	Apple	Coefficient	-0.12	-0.47	-0.40	0.51	0.295	0.35	0.06	-0.10	-0.14	0.185	-0.25	0.13	0.27	-0.31	0.166
		p-value	0.29	0.01	0.02	0.00		0.04	0.38	0.31	0.25		0.11	0.27	0.10	0.05	
2.	Pear	Coefficient	-0.05	-0.40	-0.37	0.56	0.345	0.06	-0.16	-0.24	0.12	0.085	-0.01	0.16	0.16	-0.22	0.050
		p-value	0.41	0.02	0.04	0.00		0.39	0.22	0.12	0.29		0.49	0.21	0.23	0.41	
3.	Plum	Coefficient	0.03	0.02	0.00	0.24	0.189	-0.16	-0.38	-0.40	0.34	0.173	0.09	0.01	-0.00	-0.02	0.009
		p-value	0.44	0.47	0.50	0.12		0.23	0.03	0.02	0.05		0.34	0.48	0.42	0.45	
4.	Peach	Coefficient	0.10	0.02	-0.03	-0.10	0.048	-0.14	-0.04	0.02	0.05	0.023	0.15	0.12	0.02	-0.15	0.048
		p-value	0.33	0.46	0.45	0.32		0.26	0.42	0.47	0.41		0.24	0.29	0.46	0.23	
5.	Apricot	Coefficient	0.07	-0.04	-0.07	0.12	0.024	-0.14	-0.17	-0.14	-0.05	0.122	-0.17	0.09	0.19	-0.35	0.191
		p-value	0.36	0.43	0.37	0.28		0.25	0.21	0.25	0.40		0.21	0.33	0.19	0.04	
6.	Cherry	Coefficient	0.33	0.06	-0.10	0.06		-.27	-0.17	-0.08	-0.01	0.146	0.03	0.14	0.11	-0.20	0.043
		p-value	0.05	0.38	0.31	0.40	0.191	0.10	0.21	0.36	0.49		0.45	0.25	0.29	0.16	
7.	Pomegranate	Coefficient	0.09	-0.00	-0.05	0.14	0.047	-0.15	-0.14	-0.11	0.08	0.030	-0.14	0.28	0.34	-0.33	0.13
		p-value	0.33	0.49	0.41	0.25		0.23	0.24	0.31	0.35		0.25	0.09	0.05	0.05	6
8.	Walnut	Coefficient	-0.07	0.06	0.09	-0.12	0.01	-0.12	-0.10	-0.07	0.08	0.015	0.22	0.26	0.11	-0.30	0.139
		p-value	0.38	0.39	0.33	0.28	9	0.28	0.32	0.38	0.35		0.14	0.10	0.30	0.08	
9.	Almond	Coefficient	-0.25	-0.34	-0.21	0.32	0.191	0.12	-0.06	-0.14	0.13	0.083	-0.24	0.33	0.45	-0.14	0.262
		p-value	0.11	0.05	0.16	0.05		0.29	0.39	0.26	0.27		0.12	0.05	0.01	0.25	

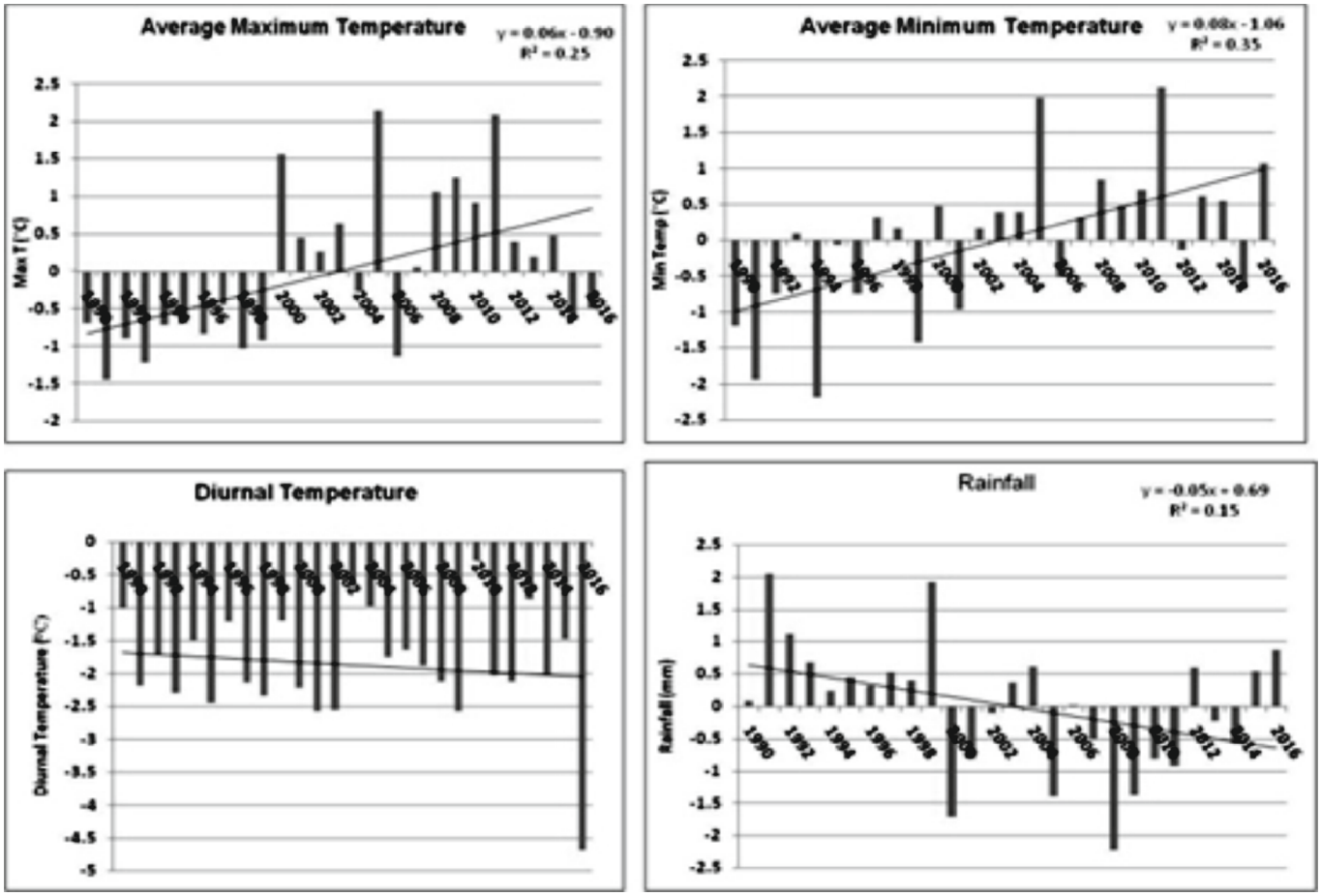

Fig. 2: SAI for average maximum, minimum, diurnal temperature and rainfall during flowering phase

three phenological stages indicating a warming trend. Impact of climatic parameters on productivity in flowering period varied from 1.5% in walnut to 18.5% in apple.

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