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Impact of changing climate on apple production in Kotkhai area of Shimla district, Himachal Pradesh

NC SHARMA, SD SHARMA*, SHALINI VERMA and CL SHARMA**

Temperate Horticultural Research Station, Kotkhai, District Shimla
***Department of Fruit Science**
****Regional Horticultural Sub-Station, Tabo, Lahaul & Spiti**
Dr YS Parmar University of Horticulture and Forestry, Nauni 173230 Solan, HP
Email for correspondence: naveen_pom@yahoo.com

ABSTRACT

To carry out the studies 9 years (2001-2009) meteorological and apple production data were taken into consideration. Data revealed that fluctuation in weather parameters (temperature, rainfall and snowfall) and shift of season from year to year had significantly influenced the apple production in the area. The annual minimum temperature increased gradually from 8.65ºC in 2001 to 12.70ºC in 2009 with an average annual increase of 0.45ºC which is a clear indication of changing climate in the area. However during the years 2005, 2007 and 2008 when annual minimum temperature was recorded slightly lower than the previous year's average minimum temperature it accounted for higher apple production (> 70000 MT). It was observed that variation in annual diurnal temperature between 11.0ºC and 20.5ºC with a mean annual temperature between 15.5-17.0ºC favored the higher apple production in the area. A positive and significant relationship was observed between minimum average temperature during different stages of fruit growth and development and apple production. However a negative but significant correlation was noted between maximum average temperature during different stages of fruit growth and development and apple production. It was observed that during the different stages of apple growing season it was not the average minimum or maximum temperatures but the variation in diurnal temperature coupled with quantum of rain or snowfall which affected the apple production. In the years when a small variation in diurnal temperature was observed with an average or good rainfall and snowfall a higher production was recorded however large variation in diurnal temperature negatively affected the apple production in spite of good rains or snowfall during the years. It was concluded from the studies that composite effect of all weather parameters viz large variations in diurnal temperature with erratic or poor rains, low or no snowfall and shift of season attributed to poor apple production in the area. Keeping in view the climate change, shift in seasons and fluctuations in weather conditions management practices need to be manipulated for sustaining the apple production in the area.

Keywords: Apple; changing climate; weather parameters; production; temperature

INTRODUCTION

Apple (*Malus domestica* Borkh) is the most important temperate fruit of the north-western Himalayan region. The apple growing areas in India do not fall in the temperate zone of the world but the prevailing temperate climate of the region is primarily due to snow covered Himalayan ranges and high altitude which helps to meet the chilling requirement during winter season. Apple is a predominant fruit crop of Himachal Pradesh and in recent years it is leading cash crop amongst fruit crops. It alone accounts for about 46 per cent of total area under fruit crops and >80 per cent of the total fruits production. The area under apple and its production has increased from 3,025 hectares and 12,000 MT in 1960-61 to 97,438 hectares and 5,10,161 MT in 2008-09 (Anon 2009). Shimla is the leading apple producing district with 3,36,753 MT which accounts for >50 per cent of total apple production of the state (Anon 2009) and Kotkhai is the major apple growing belt of district Shimla.

Production of apple fruits is an extended process which begins in the year before fruits are harvested. It starts with the formation of flower buds in the preceding summer and concludes with harvest in the next year. Weather during the late fall, winter and early spring are major factors contributing to the annual variability in the production of apples. Weather occurrences such as spring frosts (Davis 1978) and high summer temperatures during the growing season can significantly affect the production of the fruits every year. Climatic conditions during growing period therefore affect its final production especially since development occurs in an open orchard environment. Keeping in view the fluctuations in apple production pattern, perceptions with respect to decreasing trends, changes in timings of snowfall in the winters, high temperature and frequent drought spells in summers present studies were undertaken with the objective of finding out the impact of changing climate on apple production in Kotkhai area of Himachal Pradesh.

MATERIAL AND METHODS

To carry out the study last 9 years (2001-2009) data with respect to meteorological parameters and apple production in the area were recorded. The weather data were recorded at Temperate Horticultural Research Station, Kotkhai and data with respect to apple production of the area was obtained from Directorate of Horticulture, Himachal Pradesh. Keeping in view the various fruit growth and development stages of apple growing season was categorized into four stages viz dormancy or pre-flowering stage (January-March), flowering, fruit-set and fruit developmental stage (April-June), fruit developmental stage (July-September) and post-harvest stage (October-December). Data with respect to temperature, rainfall and snowfall were averaged accordingly. To work out the variation in weather parameters during different stages of fruit growth and development and fruit production from year to year co-efficient of variation was calculated by simple statistical methods. To find out the relationship between weather parameters and annual apple production correlations were established between weather parameters data during various stages of fruit growth and development and final fruit production.

RESULTS AND DISCUSSION

During the period from 2001 to 2009 a considerable variation in weather parameters viz temperature, rainfall and snowfall in Kotkhai area of district Shimla was observed. Data with respect to annual temperature and apple production (Fig 1) revealed that annual minimum temperature increased gradually from 8.65ºC in 2001 to 12.70ºC in 2009 with an average annual increase of 0.45ºC which was a clear indication of impact of global warming in the area. However during the years 2005, 2007 and 2008 when annual minimum temperature was recorded slightly lower than the previous year's temperature, a higher production of >70,000 MT was recorded. The annual maximum and mean temperatures had shown a fluctuating trend from year to year and ranged from 19.76ºC to 25.66ºC and 15.90ºC to 17.58ºC respectively. It was observed that variation in annual diurnal temperature between 11.0ºC and 20.5ºC with a mean annual temperature between 15.5-17.0 ºC favored the higher apple production in the area.

The annual total rainfall and snowfall (Fig 2) had not shown any specific increasing or decreasing trends during the years and ranged from 129.10 mm (2009) to 246.19 mm (2003) and 0.0 cm (2006) to 87.5 cm (2002) respectively. The rainfall or snowfall had no direct effect on apple production in the area but composite effect of annual temperature, rainfall and snowfall had directly influenced the apple production in the area. A large variation in diurnal temperature in spite of good rains or snowfall had a negative impact on apple production however a small variation in annual diurnal temperature ranges in spite of average annual rainfall or snowfall had favored the higher production in the area. It is clear from the fact that during the years 2001, 2002, 2003, 2005 and 2007 a good annual rainfall (>200 mm) was recorded but higher production was recorded in the years 2005 and 2007 only when diurnal temperature fluctuations were comparatively low. Similarly out of nine years taken into consideration for studies a good snowfall (87.5 cm) was recorded only once during the year 2003 and an average production was recorded during that year but during the years 2005, 2007 and 2008 higher apple production (>70,000 MT) was recorded in spite of poor snowfall of 14.0, 8.0 and 8.0 cm respectively. It could be due to reduction in the intensity and changes in timing of snowfall as during the years between 2001 and 2009. Out of these 9 years annual quantity of snowfall was recorded <10 cm in 6 years and snowfall occurred more frequently during the month of February instead of December-January. Rana et al (2008) had also reported the

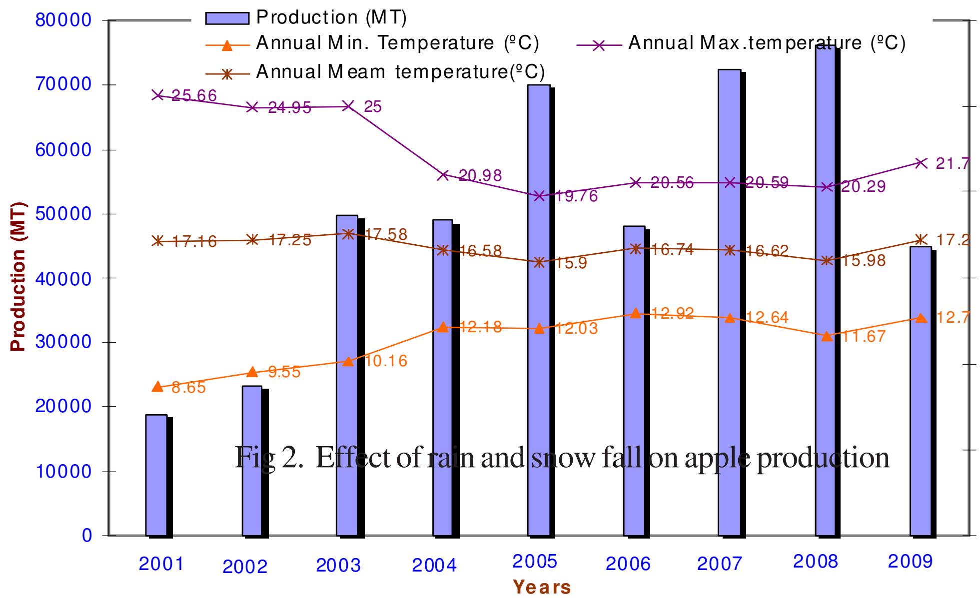

Fig 1. Effect of temperature on apple production

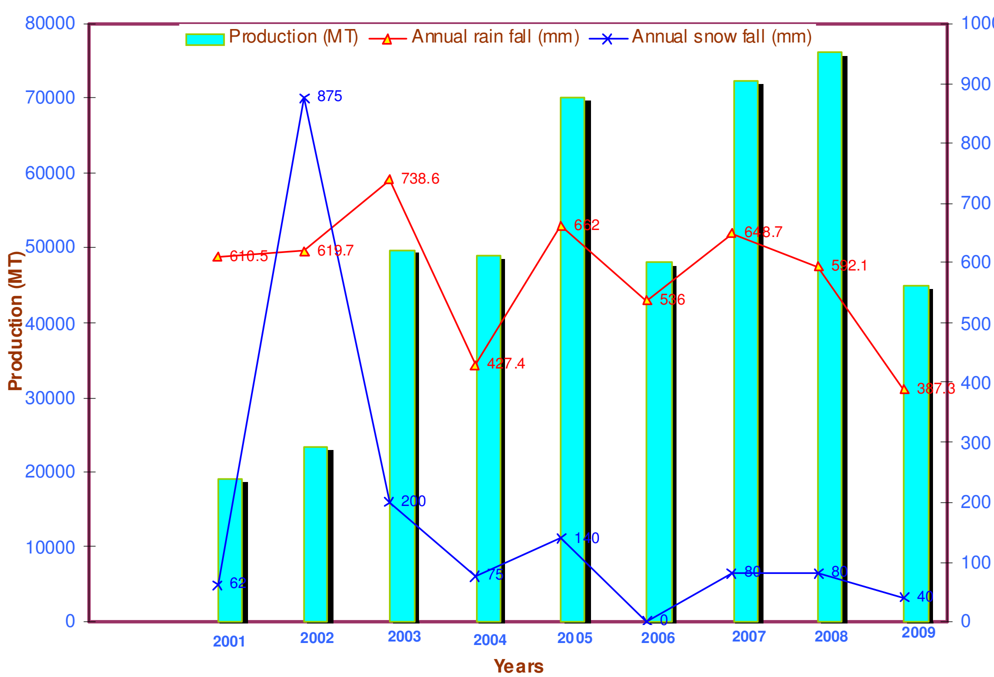

Fig 2. Effect of rain and snow fall on apple production

sharp decrease and delay in snowfall and increase in temperature while studying the impact of climate change on shift of apple belt in Himachal Pradesh. Winter temperature and precipitation especially in the form of snow are very crucial for induction of dormancy, bud break and ensuring flowering in apples (Jindal et al 2001). Beattie and Folley (1978) have also reported that weather during the pre-flowering period markedly affect the apple crop production from season to season. Snow on the ground protects roots from low soil temperatures so that the deficit of precipitation associated with poor years may reflect on the absence of protective snow cover (Caprio and Quamme 1999).

It is evident from the correlation studies (Table1) that the minimum temperature at different growing stages of a season had positive and significant relationship with apple production. Similarly annual minimum temperature had also exhibited significant and positive correlation with apple production (r=0.6854). However relationship between maximum temperature at different stages of apple growing in a year and annual production was found to be significant but negative. The correlation of annual maximum temperature and annual mean temperature with annual apple production in the area was found significant and negative with the r-values of -0.8130 and -0.7327 respectively. No relationship could be established between rainfall at different stages of growing season and apple production. However a positive but non-significant correlation was observed between annual rainfall and annual apple production in the area. Annual snowfall had exhibited non-significant and negative relationship with annual apple production. This could be due to the reason that only once in these 9 years a normal snowfall was observed but due to unfavorable other weather parameters very poor yields were recorded during that year.

A perusal of data presented in Table 2 reveal that fluctuation in weather parameters at different stages of growing season directly influenced the apple production in the area from year to year. During various stages of growing season average minimum or maximum temperature did not influence the production directly but the variation in diurnal temperatures coupled with quantity of rainfall had considerably influenced the apple production. During the dormancy or pre-flowering stage (January-March) average minimum, maximum and mean temperature as well as rainfall exhibited a coefficient of variation value of 38.45, 15.33, 12.54 and 37.81 respectively in comparison to the coefficient of variation value of 40.26 with respect to yield. This indicated that there was a direct relationship of variation in average minimum temperature and rainfall with variation in apple production. It was observed that when a small variation in diurnal temperature was observed and minimum and maximum temperatures ranged between 3ºC and

Table 1. Correlation coefficient (r-values) between fluctuating weather parameters and apple production in Kotkhai area of Shimla district, Himachal Pradesh

Weather Parameters	Apple Production Correlation coefficient (r-values)		
Temperature (Min)			
January-March (Dormancy stage)	0.0402		
April-June (Flowering, fruit set and fruit developmental stage)	0.6312	06854*	
July-September (Fruit developmental stage)	0.8013*		
October-December (Post harvest stage)	0.6181		-0.7327
Temperature (Max)			
January-March (Dormancy stage)	0.8182**		
April-June (Flowering, fruit set and fruit developmental stage)	-0.7630*	-0.8130**	
July-September (Fruit developmental stage)	-0.6395		
October-December (Post harvest stage)	-0.7878*		
Rainfall			
January-March (Dormancy stage)	-0.3159		
April-June (Flowering, fruit set and fruit developmental stage)	0.1201	0.1477	
July-September (Fruit developmental stage)	0.3039		
October-December (Post harvest stage)	0.3184		
Snowfall	-0.4115		

* Significant at 5% level

** Significant at 1% level

Table 2. Variation in apple production in relation to fluctuation in temperature and rain fall at different stages of growing season at Kotkhai area of Shimla district, Himachal Pradesh

Year	Production (MT)	Dormancy or pre-flowering stage (January-March)				Flowering, fruit set and fruit developmental stage (April-June)				Fruit growth and developmental stage (July-September)				Post harvest stage (October-December)			
		Min Temp (ºC)	Max temp (ºC)	Av temp (ºC)	Rain-fall (mm)	Min temp (ºC)	Max temp (ºC)	Av temp (ºC)	Rain-fall (mm)	Min temp (ºC)	Max temp (ºC)	Av temp (ºC)	Rain-fall (mm)	Min temp (ºC)	Max temp (ºC)	Av temp (ºC)	Rain-fall (mm)
2001	19,000	3.21	20.40	11.81	41.60	12.72	28.58	20.65	69.23	15.67	30.35	22.98	84.66	3.00	23.30	13.15	8.00
2002	23,400	5.02	18.81	11.92	76.00	13.06	30.77	21.92	34.73	14.61	29.93	22.27	90.50	5.49	20.29	12.89	5.33
2003	49,680	2.44	19.77	11.11	52.13	12.46	28.85	20.66	24.26	17.35	29.90	23.63	160.13	8.37	21.48	14.93	9.67
2004	49,000	6.90	19.03	12.97	32.33	15.00	25.97	20.49	26.80	17.23	21.58	19.41	61.03	9.59	17.34	13.47	22.30
2005	70,000	5.39	13.01	9.20	42.17	15.06	23.63	19.35	47.40	18.36	24.43	21.40	129.76	9.30	17.96	13.63	1.33
2006	48,000	7.66	16.73	12.20	41.20	15.93	23.03	19.48	55.87	18.52	24.00	21.26	71.06	9.55	18.47	14.01	10.53
2007	72,280	6.08	14.33	10.21	46.60	17.33	25.43	21.38	43.63	18.44	24.54	21.49	121.93	8.71	18.05	13.38	4.06
2008	76,000	3.00	14.90	8.95	35.13	14.89	22.75	18.82	72.40	17.90	24.64	21.27	84.10	10.87	18.87	14.87	5.93
2009	44,780	7.80	16.28	12.04	16.30	15.83	25.86	20.85	25.67	18.19	25.21	21.70	81.07	8.97	19.44	14.21	6.06
Min	19,000	2.44	13.01	8.95	16.30	12.46	22.75	18.82	24.26	14.61	21.58	19.41	61.03	3.00	17.34	12.89	1.33
Max	76,000	7.80	20.40	12.97	76.00	17.33	30.77	21.92	72.40	18.52	30.35	23.63	160.13	10.87	23.30	14.93	22.30
Mean	50,237.8	5.28	17.03	11.16	42.61	17.70	26.11	20.40	44.44	17.36	26.04	21.71	98.25	8.21	19.47	13.84	8.13
SE	6742.07	0.68	0.87	0.46	5.37	0.55	0.93	0.33	6.12	0.46	1.06	.0.40	0.40	0.81	0.64	0.24	2.00
SD	20226.2	2.03	20.61	1.40	16.11	1.64	2.80	1.00	18.38	1.37	3.17	1.20	1.20	2.43	1.92	0.72	6.00
COV	40.26	38.45	15.33	12.54	37.81	11.16	10.73	4.90	41.36	7.89	12.17	5.52	1.22	29.60	9.86	5.20	73.80

SE=Standard Error
S.D= Standard Deviation
COV= Coefficient of variance

15ºC with a mean temperature of less than 10.5ºC with good quantum of rainfall a higher apple production (>70,000 MT) was recorded. However large variation in diurnal temperature with a maximum temperature of >16ºC in spite of good amount of rains resulted in poor apple production (<25,000 MT) in the area. The explanation for the association of a deficit of large diurnal temperature ranges with good production is that large diurnal temperature ranges are likely to be associated with more occurrences of extremely low night temperatures during the winter season and are also likely to be associated with more days with high day temperatures during the growing season. The deficit of large diurnal temperature ranges and the associated lack of extreme temperatures during the seasons favored the production of a good apple crop (Caprio and Quamme 1999).

During the flowering, fruit set and fruit developmental stage (April–June) coefficient of variation values of 11.16, 10.73, 4.90 and 41.36 were recorded for average minimum, maximum and mean temperature as well as rainfall respectively. However this value for yield was 40.26. This indicated that during this period rainfall had direct influence on variation in apple fruit production. It was observed that a lower variation in diurnal temperature between 14.8ºC and 25.5ºC with good rains resulted in higher apple production whereas large variation in diurnal temperature (minimum temperature <14ºC and maximum temperature >28ºC) during the flowering and fruit set stage resulted in poor apple production. In the year 2006 even after congenial temperature conditions during flowering and fruit setting stage poor apple production was recorded due to no snowfall during dormancy period and excessive rains at flowering and fruit set stage as well as poor rains during monsoon. In the years of poor production high temperature and less soil moisture condition in the form of low rainfalls during fruit growth and developmental stage had perhaps attributed to decreased production. Caprio and Quamme (1999) reported that high temperatures after pollination induce early fruit abscission (June drop).

Large variation in weather parameters during fruit growth and developmental stage (July-September) greatly influenced the apple production. During this stage the coefficient of variation values of 7.89, 12.17, 5.52 and 1.22 were recorded for average minimum, maximum and mean temperature as well as rainfall respectively in comparison to coefficient of variation value (40.26) for yield. During this stage a diurnal temperature variation between 17.9ºC and 25.0ºC with good rainfall (>80 mm) favored higher apple production in the area. However frequent dry spells in the form of low rainfall and higher variation in diurnal temperature resulted in poor fruit production. Caprio and Quamme (1999) had also made similar observations and reported that high temperatures from mid-July to the end of August did not favor the apple production. Lack of precipitation might be associated with high day temperatures and soil moisture deficits are associated with periods of high day temperatures. Drought stress during the stage might have reduced crop size by lowering net photosynthesis and decreasing fruit size. Jones (1983) has reported increase in respiration with high night temperatures that leads to a reduction in net photosynthesis. Thus low production might be resulted from reduced net photosynthesis.

During the post-harvest stage (October-December) average minimum, maximum and mean temperatures as well as rainfall exhibited a coefficient of variation value of 29.60, 9.86, 5.20 and 73.80 respectively in comparison to the coefficient of variation value of 40.26 with respect to yield. This indicates that rainfall during the stage had great influence on the annual apple production. During this stage a small variation in diurnal temperature with minimum temperature of >8.5ºC and maximum temperature of <18.5ºC and good rainfall favored the fruit production during the next year. However large variation in diurnal temperature with minimum temperature <8.5ºC and maximum temperature >20 ºC and poor rainfall had a negative impact on apple production during the next year. It might be due to the heat or drought stress as high day temperature and lack of rainfall during autumn adversely affect the production and delay the flower bud differentiation. Delays in flower differentiation lead to low flower production and poor fruit set during the following spring (Buban and Faust 1982).

It is concluded from the studies that annual minimum temperature is gradually increasing in the area from year to year. However annual maximum and mean temperatures along with rainfall and snowfall are fluctuating from year to year and these fluctuating weather conditions especially extreme diurnal temperature and no or low snowfall during winter and high temperature and drought spells during summer are considerably influencing the apple production. To overcome the adverse effects of fluctuating weather conditions proper selection of suitable cultivars as per the altitude and microclimatic conditions of the area is required with the proper proportion of pollinizing varieties. Management practices need to be improved using plastic mulches and micro-irrigation (drip and sprinkler) systems to maintain the soil moisture and lowering the temperature during drought spells in the summer months and using sprinklers and wind machines during late spring to protect the plants from frost and low temperature.

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