International Journal of Applied and Pure Science and Agriculture
ISSN Online - 2394-5532 Impact Factor : 4.446 by SJIF ISSN Print - 2394-823X

IMPACT OF VARYING CLIMATE CONDITIONS ON APPLE A CASE STUDY OF SHIMLA DISTRICT, HIMACHAL PRADESH

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Abstract

The mountain ecosystems are facing the challenges posed by increasing seasonal variability, which affects the agriculture and horticulture crops. In this paper an effort has been made to analyze the impact of climatic factors on apple production in district Shimla of Himachal Pradesh. To accomplish this objective, the secondary data has been obtained and analyzed which reveals that in the last thirty years, the area under apple cultivation has increased and apple has emerged as one of the major crops, but there is varying trend in production due to the impact of climatic factors and incidence of pests and diseases.

Keywords-Climate Change, Apple cultivation, Apple production, chilling hours, horticulture

I. INTRODUCTION

Climate change involves fluctuations in temperature, precipitation, and climatic excesses. It also manifest in form of changes in atmospheric Co2 level and ground-level ozone concentration, besides deviances in sea level [1]. The mountain ecosystem are presently facing the challenges posed due to increasing seasonal variability, including aridity, warmer winters, inconsistent precipitation, and unpredictable frosts and storms, which largely pose threats to agriculture and horticulture crops. Change in plant phenology is one of the earliest responses to rapid global climate change and could potentially have serious consequences for plants which depend on climatic conditions, and horticulture plants are no exception to this. In New York unfavorable weather was one of the several factors which results in loss of fruit crops during blooming time [2]. Researchers studied the risks of spring frost on apples in a strategic area for Europe [3]. In Slovenia climate change impacts the winter chilling with negative consequences on fruit yield and quality because most temperate fruit and nut species require adequate winter chilling for normal production [4]. Researchers investigated the long-term and short-term effect of climate change on apple production in Kotli Sattian area of Rawalpindi District, Pakistan using *Malus domestica* var. *Ambri* L. as an indicator. Climate data for 30 years was correlated with net apple production per year. The investigation revealed that production declined mainly due to drastic climate change including unusual seasonal variations, elongated summer periods and unusual rainfall periods [5]. A study in Japan showed the impact of climate change on horticultural crops, which affects the quality of fruits, for example, peel coloring, rapid softening and spoiling of fruits [6]. Researchers provided evidence that the taste and textural attributes of apples change because of recent global warming in Japan [7]. A WWF Report (2015) on Australia stated that apples are sensitive to extreme heat conditions with very hot conditions during the maturation period [8].

All factors influencing the yield of apples were manageable but the climatic factors were beyond control [9]. Researchers provided viewpoint on different adaptation in building resilience of short duration versus long lived horticultural crops [10]. Fruit yield depends on a narrow range

temperature and rainfall in magnitude and timing. He revealed that temperature determines quantity and quality of fruits produced. Higher temperature at the fruit development stage speeds-up maturity, fruit size and quality [11]. Researchers showed that climate change affects the chilling requirement of temperate fruit crops significantly and therefore, the opportunity to meet this requirement will be reduced as the climate becomes warmer. Increase in average global temperature has shifted the existing plant species and varieties to new latitudinal belts with favorable climates [12]. A study at two locations in Himachal revealed prevalence of lower average temperature and its impact on delaying the flowering time of apples [13]. Role of environmental conditions on flowering and yield in apple in district Kullu of Himachal Pradesh was studied and it was found that that low temperature during the winter promote rest completion, whereas the high temperatures interspersed with low chilling temperature retard this process [14]. Impact of climate change on apple output was studied and linkages between productivity and weather parameters have revealed '*temperature variations'* as pivotal factor in disturbing the hydrological cycle and intensity of occurrence of other parameters [15]. Researchers carried out a study in Lahaul-Spiti, Kullu and Shimla district and highlighted that temperature in apple growing regions of the mountain state of Himachal Pradesh showed increasing trends whereas precipitation showed decreasing trends. They further revealed that climate change has demonstrated its impact with the decreasing productivity of apple crops in recent years at lower elevations, providing opportunity for more apple cultivation at higher elevation regions of Himachal Pradesh [16]. Researchers correlated the meteorological and apple production data for years (2001-2009) in Kotkhai area of district Shimla and 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 [17]. Perceptions of farmers regarding the effect of climate change on apple farming along the altitudinal gradient were studied in District Kinnaur [18]. Winter temperature and precipitation in form of snow are important and sensitive climatic factors for induction of dormancy, bud break and also to ensure proper flowering in apples. Trend analysis indicated that snowfall is decreasing at the rate of 82.7 mm/annum in the entire region. Consequences of climate changes are clearly visible in shifting of apple cultivation from lower elevations to higher altitudes in HP [19]. In Himachal Pradesh apple cultivation is expanding to higher altitudes whereas lower altitude areas where apples was grown had become unsuitable because of rise in temperatures during winters. Phenological changes were correlated with climatic parameters [20]. The present paper is based on a carried out to study the effect of changing climatic conditions on flowering, yield and production of apple in Shimla district.

II. METHODOLOGY

The paper is an outcome of the analysis of secondary data, which was collected from Directorate of Horticulture, H. P. Shimla, Dr. Y. S. Parmar University of Horticulture and Forestry, Nauni, Meteorological Department and H. P. University. Regional Horticultural Research Station, Mashobra, which is a Regional Station of Dr. Y.S. Parmar University of Horticulture and Forestry, was also visited for the purpose. Various national and international journals, books, monographs, reports of government were also consulted for the purpose.

Study Area: Himachal Pradesh located between $30^{o}22'$ and $33^{o}12'$ N latitude and $75^{o}47'$ and $79^{o}4'$ East longitude comprise of four agro-climatic zones with an altitude range 350 to 7000 meters above mean sea level receives 18 to 300 cm of rainfall. After Jammu & Kashmir, Himachal Pradesh is the second largest producer of apples with District Shimla being the highest, in India [21]. Due to its location, a variety of fruit crops are grown here. The variety of apples in Himachal Pradesh is not broad and comprises of Delicious Apples, which is 83 percent of the total apple production. This variety is highly sensitive to fluctuation in temperature. More commonly the changes are visible in local climate. Over the years farmers have noticed variations to blossoming, fruit-setting, yield and increased incidents of pests and diseases in response to changing climatic conditions. Due to climate change the challenges faced by apple growing farmers' have also increased in Himachal Pradesh.

III. RESULTS AND DISCUSSION

Apple Cultivation: General Trends: Apple (*Malus domestica* Borkh) is one of the most important temperate fruits of the north-western Himalayan region and a main fruit crop of Himachal Pradesh. About 46 percent of the total area under horticulture is utilized for apple cultivation and accounts for >80 percent of the total fruit production. The area under apple cultivation has increased from 3,025 hectares in 1960-61 to 97,438 hectares in 2008-2009. Shimla is the main apple producing district which accounts for >50 percent of total apple production in the state [22]. However, along with these benefits, certain obstacles have also come into being. The most vital and well-known impediment is climate change. It has been observed that in last few years, the climate is changing. It is not a good indication for food production and specifically the apple production. Since last few years snowfall is not occurring in time and at times there is no snowfall. Earlier the months of December and January used to receive enormous snowfall but over the years a significant decrease in the actual amount along with the extended period of snowfall through the months of February-March has been noticed. Weather conditions, like, uninterrupted rainfall, low and inconsistent temperature and incidence of frost during flowering, affects pollination and fruit-quality negatively and also reduce the yield. During flowering, extreme cold condition has maximum effect on apples. The production of apple has been affected due to heavy and constant rain and temperature fluctuations during flowering. Apple growing areas of lower belts (below 6500 feet) suffered the most while the higher belts (above 6500 feet) were able to cope-up the erratic conditions [23]. There were huge year to year fluctuations in production of apple production due to infrequent rains and hailstones. These problems further got aggravated by climate change caused due to global warming. In the recent years, a notable shifting of climate has been observed in apple growing belts. Earlier low-lying areas of Himachal Pradesh were also suitable for apple growth, but now the apple growing belts are being shifted to higher elevations. The primary cause of this shift is higher temperature during the winters which affects the overall production, flowering and pollination. India produces all deciduous fruits including apple and pear and stone fruits like peach, plum, apricot and cherry, in substantial quantity. These are mainly grown in the North-Western states of Jammu and Kashmir, Himachal Pradesh and in hills of Uttar Pradesh. The North-Eastern Hills region, comprising of the states of Arunachal Pradesh, Nagaland, Meghalaya, Manipur and Sikkim also grows deciduous fruits. The state-wise trend in area under cultivation and production in the recent years is presented in table 1, which shows that till 2013-14, the area under cultivation of apple is highest in Jammu and Kashmir followed by Himachal Pradesh, Uttarakhand and Arunachal Pradesh.

Table 1: State-wise area and Apple Production in India

Year	Jammu & Kashmir		Himachal Pradesh		Uttarakhand		Arunachal Pradesh		Others	
	A	P	A	P	A	P	A	P	P	A
2007-08	126.4	1268.5	94.5	592.6	32.2	130.5	10.8	9.8	0.5	0.04
2008-09	180	1845.7	97.2	510.2	42	145.5	25	10	0.3	0.9
2009-10	138.1	1373	99.6	280.1	32.4	114	12.8	10	0	0
2010-11	141.7	1373.2	141.7	892.1	33	135.9	12.8	10	0.1	0
2011-12	170.6	1348.2	103.64	275.04	33.7	122.7	13.9	30.5	0.1	0
2012-13	157.28	1775	106.23	412.40	33.76	123.2	14.07	31	0.6	0.2
2013-14	160.9	1847.7	107.69	738.72	30	77.5	14.3	31.9	2	0.2

Source: National Horticulture Board P= Production in 000'MT A= Area in hectares

Through there have been varying trends in both area under cultivation and production, still Himachal is at second rank in terms of production after Jammu and Kashmir. Though the production of apple has gradually increased but the productivity has fallen, the reasons being climate variability, pest attack, soil factors, etc. The climate change in the form of unpredictable precipitation, increasing temperature, reducing chilling hours have started affecting the horticulture and eventually the food security systems. Besides this, majority of fruit orchards in Himachal Pradesh are located in unfavorable and marginal conditions, with respect to climate, topography and availability of suitable

soils, etc. and the cultivation is carried out mostly on sloppy and marginal lands with appropriate rain-fed conditions. Thus, chances of pre and post-monsoon droughts, soil erosion and nutrient losses are quite common. Hence, the adverse effects of climate under unfavorable conditions can be mitigated by properly analyzing the scenario.

Impact of Climate Change on Apple Cultivation: Climate change has become a serious concern for apple production. Horticulture in Himachal is mostly shaped by climate rather than any other factor. The goal of an agriculturalist is high yield and good quality crop that satisfies the end user. Numerous agronomic aspects may affect the yield and quality, even though they are under the control of an agriculturalist. These include farming systems, climate and soil conditions. The perfect range of precipitation for good apple production is 100-125 cm, which must be uniformly distributed all through the year. The normal pre-requisites of apple cultivation are presented in table 2.

Table 2: Standard Pre-requisites for Apple Cultivation

Altitude	:	1,500-2,700 meters above mean sea level
Chilling requirements	:	1200-1500 hours of chilling below 7°C
Temperature (winters)	:	7^0C
Temperature (developing time)	:	21-24^0C
Temperature (pre-flowering phase)	:	12^0C
Temperature (flowering phase)	:	15-18^0C
Temperature (fruit growth phase)	:	21-24^0C
Temperature (post-harvest phase)	:	15^0C
Precipitation	:	100-125 cm, evenly distributed throughout the year
Soil	:	Loamy soil
pH of soil	:	5.5 to 6.5
Other requirements	:	Appropriate drainage and ventilation

Source: Gupta, S. K. and Gupta, R. Package of Practices of Food Products. Directorate of Extension Education, Dr. Y. S. Parmar University of Horticulture and Forestry, Nauni, Solan

The most suitable range of temperature must be 7^0C in winters and 21-24^0C during the developing season. The appropriate height for apple is between 1,500-2,700 meters above mean sea level. Unnecessary rains and fog at the time of maturity may results in poor fruit quality. It may leads to improper color development and fungal spots on fruit's outer surface. In addition to this, loamy soils rich in organic matter having pH range of 5.5 to 6.5, appropriate drainage and ventilation are required for apple cultivation. However, poor soil produces bad results. Thus, best results can be seen in fertile loamy soil. Soils should be well-drained. Wet soils lead to poor aeration and increased rate of crown rot in apples. Generally wet soil restricts the development, resulting in poor anchorage of tree. Extreme soil pH values result in nutrient tie-up or toxicity and poor tree and fruit development. A variety of pre-harvest factors can modify the appearance of fruit crop to be harvested. These include:

(1) Biological aspects (pathological, entomological, etc.);
(2) Physiological aspects (physiological complaint, nutritional disparity, ripening);
(3) Environmental aspects (e.g. climate, soil, water relation, light intensity);
(4) Mechanical aspects;
(5) Extraneous matter; and
(6) Genetic disparity and deviations

Apple farming can be divided into following stages with specific climatic requirements:

- Dormancy or pre-flowering stage (January-March)
- Flowering, fruit-set and fruit development stage (April-June)
- Fruit growth and development stage (July-September)
- Post-harvest stage (October-December)

In order to study the impact of changing climatic conditions on apple production the data was gathered from the relevant sources and analyzed. It was found that apple production has shown significant changes with varying climatic parameters, viz., temperature, rainfall and snowfall. The area under production has increased gradually, but the average productivity of apple in Himachal Pradesh is 3.3 MT/ha, which is lower than the national productivity of 5.1 MT/ha and much lower

than that of Jammu and Kashmir with 10.1 MT/ha. The data collected from State Horticulture Board is presented in the table 3, which shows that during 1985-99 the production of apple in district Shimla has decreased even though the area under cultivation has increased. This is attributed to the fact that the chilling conditions required during the flowering stage could not be achieved due to higher temperature in the months of December, January and February even though the precipitation was appropriate. The subsequent years received bumper production along with enormous increase in the area under apple cultivation. The production decreased all of a sudden in the year 1994-95, nevertheless the area under cultivation showed a gradual increase. In spite of having ideal precipitation range in 1994, the reason behind reduced production was increased temperature during the flowering and incidence of spring frost. In year 1995, premature leaf fall affected more than 40 percent of all apple orchards in Himachal Pradesh. According to the researchers, due to premature leaf fall, the quality of produce was affected badly and fruit bearing capacity decreased [24]. Later a study carried out in 2000 revealed that the reason behind premature leaf fall was incidence of fungal disease called Marssonina Blotch or more commonly '*Apple Blotch'* [25].

Year 1994 and 1999 were the hottest years of the decade. Again, in the year 2000, the production of apple saw a tremendous downfall where the production decreased (20536 MT) from lakhs to thousands in Tons. This is attributed to the fact that high temperature affected the crop during the dormancy or pre-flowering stage. Moreover the precipitation was comparatively low during the flowering, fruit-set and fruit developmental stage. The ideal temperature during the pre-flowering phase is 12^0C while in flowering stage, fruit growth and post-harvest phases, it should be 15-18^0C, 21-24^0C and 15^0C. Table 3 shows that the annual temperature in 1985-1986 was quite high during all three phases, i.e., 14.44^0C in pre-flowering phase, 26.90^0C in flowering phase, 25.26^0C in fruit-growth and development phase besides a quite warm winter during the post-harvest phase. Thus, the production during this year faced a major reduction. Similarly, in the year 1990-91, the production of apple went down to 243042 MT which was 243938 MT in 1989-90 due to higher temperature during all phases of apple growth. In the year 1989-90, the ideal temperature during the three phases was more or less maintained while in 1990-91, it was 2.78^0C more than the previous year. This is believed to have affected the production. In 1994-95, there was a major decline in production from 172851 MT in 1993-94 to 75250 MT. In 1999-2000, the same trend was witnessed with a temperature difference of 5.40^0C between 1999-2000 and 1998-1999. The subsequent years showed a gradual increase in production due to favorable climatic factors, but again in 2006-2007, there was a minor decline in apple productivity. Lower temperature in March and higher temperature during the winters affected the flowering pattern and in turn the yield. In the year 2006-2007, the rainfall was comparatively lower than previous years during the flowering, fruit-set and fruit developmental stage.

Table 3 shows that in the subsequent years, like 2009-10 a drastic fall was noticed from 171945 to 336753 in the preceding year. Year 2009-10 experienced the most severe drought and inappropriate chilling hours, which affected the production. A higher temperature was recorded in all the phases, i.e., 17.66^0C during the pre-flowering, 27.90^0C during the flowering, 24.76^0C during the fruit growth stage and 16.66^0C during the post-harvest.

In 2011-12, the production rolled down due to insufficient rainfall and warmer weather. In 2014-15, a decline of 91671 MT was noticed from the preceding year due to high temperature, which affected the dormancy, bud-break, fruit-set and chilling hours of the apple plants. Table 3 shows that during the years 2006, 2007 and 2008, when the annual average temperature was recorded slightly lower than the preceding years temperature, a higher production of was recorded. The annual maximum and mean temperatures showed an inconsistent trend from year to year, ranging from 19.76ºC to 25.66ºC and 15.90ºC to 17.58ºC respectively.

From the table 3, it is clear that 2010-11 followed by 2013-14 made a bumper production of 602684 MT and 499422 MT apples respectively due to appropriate climatic conditions. It was observed that variation in the annual diurnal temperature between 11.0ºC and 20.5ºC with a mean annual temperature between 15.5-17.0 ºC favored the better apple production.

Table 3: Area (in ha) under Apple Cultivation and Production (in MT) in Shimla vis-à-vis the Climate Change

Year	Area under cultivation (in Hectare)	Dormancy or pre-flowering stage (January-March)		Snowfall (in cms)					Flowering, Fruit-set and fruit developmental stage (April-June)		Fruit growth and developmental stage (July-September)		Post-harvest Stage (October-December)		Production (in MT)
		Avg. Temp. (in ° C)	Avg. Rainfall (in mm)	Dec	Jan	Feb	March	Total	Avg. Temp. (in ° C)	Avg. Rainfall (in mm)	Avg. Temp. (in ° C)	Avg. Rainfall (in mm)	Avg. Temp. (in ° C)	Avg. Rainfall (in mm)	
1985-86	21611	14.44	15.86	0	0	0	0	0	26.90	74.04	25.26	299.94	16.68	25.22	87593
1986-87	21939	13.19	24	12	7	21	9	49	25.38	58.03	25.03	263.96	16.44	78.60	238364
1987-88	22453	14.19	34.4	1	0	15	0	16	25.4	39.80	26.96	95.10	17.34	19.43	171522
1988-89	23266	14.69	31.1	0	0	0	0	0	27.07	47.73	25.24	277.66	16.84	19.10	105176
1989-90	23980	12.67	37.2	205	0	22	10	237	25.10	28.56	24.88	184.43	16.67	23.30	243938
1990-91	25191	14.08	57.1	0	0	13	33	46	26.52	48.13	24.94	266.90	16.66	6.80	243042
1991-92	26754	13.39	16.7	7	6.6	30	54	97.6	25.35	76.93	25.76	127.26	16.44	18.70	208247
1992-93	27916	13.59	46.4	0	109	26	43	178	25.81	40.16	24.86	177.53	17.66	0.06	191961
1993-94	29123	13.39	23.03	2	1	1	0	4	26.16	68.13	25.39	152.06	17.34	3.06	172851
1994-95	30114	14.60	20.76	7	20	28	10	65	26.23	43.40	25.57	208.43	16.98	14.00	75250
1995-96	31213	12.87	69.43	0	0	0	0	0	27.04	45.90	24.51	259.50	17.57	7.83	199373
1996-97	31956	14.62	53.36	12	5	24	17	58	25.83	100.80	24.01	241.46	16.18	17.60	201781
1997-98	32908	13.81	18.53	28	19	0	63	110	25.02	104.00	25.90	171.80	15.73	15.46	127341
1998-99	33707	12.26	42.3	0	37	15	44	96	26.97	28.80	25.87	205.83	17.98	7.76	258621
1999-00	34465	15.70	18.46	11	26	40	20	97	27.88	48.83	26.51	150.50	18.39	1.13	20536
2000-01	35052	13.68	32.23	0	0	0	0	0	27.04	69.23	26.02	84.66	18.99	8.00	274056
2001-02	27678	14.81	39.1	4	7	10	0	21	26.18	34.73	26.52	90.50	18.74	5.33	110857
2002-03	28247	14.91	31.9	22	17	20	29	88	27.50	24.26	25.85	160.13	17.87	9.67	229207
2003-04	29029	14.94	89.8	56	96.6	67	52	271.6	25.70	26.80	29.3	61.03	19.35	22.30	294402
2004-05	29671	18.03	43.8	4	10	0	0	14	25.33	47.40	25.46	129.76	17	1.33	318449
2005-06	30666	14.94	103.5	0	0	0	0	0	24.98	55.87	25.43	71.06	15.66	10.53	310252
2006-07	31323	13.90	62.3	6	0	2	0	8	25	43.63	24	121.93	16.66	4.06	163301
2007-08	32195	13.99	283.4	2	2	3	1	8	24.96	72.40	24.25	84.10	18.33	5.93	349262
2008-09	32586	14.36	46.5	6.5	8.7	3	1	19.2	26.21	25.67	25	81.07	18	6.06	336753
2009-10	33579	17.66	24.26	0	1.8	4	0	5.8	27.90	39.23	24.76	169.26	16.66	9.46	171945
2010-11	34612	16	38.03	3.5 mm	8.5mm	14.5mm	22.5mm	4.9	29.66	75.16	28.33	281.83	19.33	29.20	602684
2011-12	35778	16	42.46	51	95	0	77	223	31.66	83.50	29	174.23	11	4.16	168634
2012-13	37249	15.66	54.16	14	63.6	43	0	120.6	30.33	40.50	29.33	181.46	18.33	7.16	259779
2013-14	37542	15.33	138.4	7 inch	6.5 inch	0	0	13.5 inch	30.33	119.10	28.66	193.50	19.33	31.13	499422
2014-15	38781	16	101.1	5	1	0	0	6	30	58.30	29	146.33	15	24.33	407751

ɔurce: Directorate of Horticulture, Shimla, Water Portal of India, Meteorological Department of Himachal Pradesh, RHRS, Mashobra

Iote: Avg. = Average

The table 3 further reveals that during the years 2001, 2002, 2003, 2005 and 2007, an optimum annual precipitation (>200 mm) was recorded but higher production was recorded in the years 2005 and 2007 only, when the diurnal temperature fluctuations were relatively low. In the year 2003, a moderate snowfall (87 cm) was recorded and thus an average production was recorded but during the years 2005, 2007 and 2008 higher apple production 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 fluctuations in the timing of snowfall. Thus, it can be inferred from the data that snowfall pattern has showed an inconsistent pattern. It is evident from the table 4.4 that except for the years 1989-90, 1996-97, 1997-98, 1999-2000, 2003-04, 2002-03, 2004-05, 2008-09, 2010-11, 2011-12, 2012-13, 2013-14 and 2014-15 snowfall occurred more frequently during the months of February instead of regular timings of December-January. As a matter of fact, the water requirement of trees increases during the spring season when the surface area of leaf increases. The water requirement of a tree increases with air temperature or higher intensity of sunlight. Hence, there is probability of water deficiency in the trees even though there is sufficient soil water. The data obtained from State Horticulture Board of Himachal Pradesh reveals that in the last thirty years, the area under apple cultivation has increased in district Shimla and apple has emerged as one of the major crops, but there is varying trend in

production due to the impact of climatic factors and incidence of pests and diseases. Thus, in order to earn more profit, the farmers have started substituting traditional crops for apple cultivation.

CASE STUDY: REGIONAL HORTICULTURE RESEARCH STATION, CRAIG NANO

The Regional Horticulture Research Station is located at a distance of sixteen kilometers from Shimla on Shimla-Tattapani-Mandi highway. It is situated at 31.1^0 N latitude and 77.1^0 E longitude, North-west of Shimla with an elevation of 2286 meters above msl. The climatic and other requirements at station are presented in table 4. Regional Horticulture Research Station (RHRS) is mainly carrying out research on temperate fruits since its beginning in the 1953 under the department of agriculture and later in 1958 it was named as Regional Fruit Research Station. It is playing a leading role in research and transfer technology on temperate horticulture. This station was developed from an apple orchard setup by Mr. Alexander Coutts, a tailor to the then Viceroy of India Lord Dufferin who originally established the orchard known as '*Hillock's Head*' in the year 1887 where apple, pear, plum and a number of exotic ornamental plants including many varieties of roses were planted. Later it was named as '*Coutt's Garden*', where a few English varieties of apple such as Yellow Newton, King of Pippin and Granny Smith were introduced. Since December 1985, it is a leading Regional Horticultural Research Station of Dr. Y. S. Parmar University of Horticulture and forestry, Nauni, Solan (HP) and a Centre of Excellence for sustainable apple production. It has the biggest germplasm of apples, pear and cherries in India. At present, about 238 varieties of apples, 63 varieties of pears, 47 varieties of cherry and cultivars of hazelnut and walnut are kept in the repository. Other fruits like Cherries, Apricot, Pear, etc. are also cultivated here. List of the varieties of apple available in the station are given in table 5.

Table 4: Climate and Topographical Conditions at RHRS, Mashobra

Area	64 acres
Soil Type	Clay loam to clay Fairly deep pH= 6.5
Annual rainfall	135 to 150 cm (monsoon rains during July to September)
Temperature	Does not exceed 29.4^o C in summers Does not go below - 4^o C in winter months

Source: Regional Horticulture Research Station, Mashobra

Table 5: Apple Varieties grown at RHRS, Mashobra

Apple	**Varieties**
Standard Cultivars	Royal Delicious, Red Delicious
Improved Early Coloring Strains	Vance Delicious, Top Red, Hardeman, Skyline Supreme, Bright-N-Early and Real Mecoy
Spur type Cultivars	Red Chief, Oregon Spur, Silver Spur, Well Spur, Red Spur, Starkrimson Delicious, Gold Spur, Stark Spur Golden
Promising introductions	Scarlet Gala, Gale Gala, Red Fuji, Coe Fuji, Early Red One, Scarlet Spur-II, Oregon Spur-II, Gibson Golden, Red Gravenstein
Pollinizers	Tydeman's Early Worcester, Red Gold, Granny Smith, Lord Lambourne, McIntosh, Golden Delicious and flowering crabs (Manchurian, Golden Hornet, Snow Drift)
Hybrids Developed	Ambred, Ambroyal, Ambstarking and Ambrich

Source: Regional Horticulture Research Station, Mashobra

Table 6: Production trend of Royal Delicious and Vance Delicious at RHRS, Mashobra

Year	**Avg. Temp. (in ^{0} C)**	**Avg. Rainfall (in mm)**	**Royal Delicious (in kgs)**	**Vance Delicious Yield (in kgs)**
2001	19.79	74.25	122	258
2002	20.22	146.25	233 kg 500 g	285

2003	21.57	92.83	201 kg 400 g	291
2004	22.07	130.5	Nil	Nil
2005	21.59	123.83	64	76
2006	21.47	116.25	8	2
2007	21.27	99.91	462	670
2008	21.10	102.91	263	223
2009	21.03	109.91	132 kg 300 g	174 kg 200 g
2010	19.80	132.41	420	674 kg 500 g
2011	20.69	101.33	2 kg 1800 g	-Nil-
2012	19.08	88.50	169	223
2013	21.10	64.91	112	219 kg 100 g
2014	19.70	53.83	Data not recorded	Data not recorded
2015	18.37	113.91	366 kg 800 g	277 kg 525 g

Source: Regional Horticulture Research Station, Mashobra

Recently, the station has imported strains of Starkrimson, Red Spur, Top Red, etc. It is envisaged that in future, improved strains of apple will be available. Though a number of varieties of apple is cultivated at this station, but the production trend for two varieties, i.e. Royal Delicious and Vance Delicious, vis-à-vis impact of climatic factors has been presented in table 6. According to meteorological data gathered from RHRS for the period 2001-2015, years like 2001, 2005, 2006 and 2011 showed much lesser yield of Royal Delicious variety due to warmer climate. In 2004, excessive rainfall destroyed maximum plants of Royal Delicious. But, the year 2008 and 2010 experienced remarkable production due to good precipitation. As per the annual average temperature data, there is an annual increase of annual temperature with a difference of 0.84^{o}C with 21.10^{0}C in 2008 to 21.03^{0}C in 2009. In spite of sufficient rainfall in years 2004 and 2006, the productivity was not good. Drought like conditions and warmer climate in 2014 with low rainfall, affected the apple production. As far as Vance Delicious is concerned, years 2004, 2011 and 2014 had fluctuations in temperature which eventually reduced the yield of this variety. 2004 received unexpected rainfall and 2014 experienced severe drought, which declined the production. In 2011, the productivity was nil because of pest attacks on majority of apple plants.

Climate change refers to the variation in the climate over a period of time which occurs as a result of direct or indirect human activity that modifies the structure of global environment. In last century, the average temperature of earth's surface has increased by about 0.74°C [26]. It has been reported that the decade of nineties was the warmest in the last millennium and 1998 was the hottest year [27]. Increasing concentration of greenhouse gases like carbon-dioxide, methane, nitrous oxide and chlorofluorocarbons due to rapid industrialization are accountable for changing climate. It is expected that global temperature would rise by up to 6°C by the end of the 21st century compared to pre-industrial levels [26]. The rise in temperature is likely to affect the transpiration index which would deplete the water content of soil resulting in water stress in plants during the dry spell. This in turn will reduce the crop productivity and accelerate fruit ripening [28].

It was found that climatic factors are adversely affecting the apple production in the study area. The reduced production and apple size, poor color, etc. affect the production trend. Thus, the results of present study are in harmony with the inferences drawn by Jangra and Sharma 2013, who reported that global warming, is resulting in loss of vigor, fruit-bearing capacity, decreased fruit size, reduced juice content, colour change, diminished shelf-life and increased incidence of pest attack thus causing low production and poor apple crop. Thus, it is anticipated that vulnerability, infrequency and rapid loss of many species of temperate fruits will be the penalties of changing climate in near future [29].

Cold winters are vital for accomplishing the chilling requirements in apple which ensures consistent flowering, fruit set and adequate yields. To escape the damage of delicate tissue from

wintertime, trees of temperate or cold climates have developed the method of dormancy. After chilling, the endo-dormancy is broken and the tree is prepared to continue the growth in the subsequent spring season [30]. Researchers also reported that winter temperatures and precipitation, especially in the form of snow, are critical for inducing dormancy, bud break and ensuring flowering in apples. Less than 1,000 chilling hours, results in a poor fruit set which consequently leads to poor yield. These changes in climate are also affecting the lifecycle of pollinizers. The non-fulfillment of basic requirements results in abnormal growth of tree. Depending on the type of cultivar, the apple tree requires 1200-1500 hours of chilling below 7°C [31]. However, the analysis of data reveals that with changing climate, these requirements could not be achieved and thus affecting the apple production in district Shimla.

Variation in the chilling affects the dormancy breaking process, probably in response to climate change [32]. The analysis made by Legave *et al*. 2013 are consistent with the findings of present study, wherein it has been reported that the rise in mean temperature, long drought spells during midsummers, delayed beginning of winter, decreased snowfall have not only affected apple production but also the area under apple cultivation. Similar observation made by Vedwan and Rhoades states that climatic changes alter the pattern of blossoming, bearing and, therefore, fruit yield, and the quality of apple under Western Himalayan condition of India, supports the findings of present study [33]. Vedwan in 2006 made similar observation by reporting a significant production loss in apple in district Kullu of H.P. The reason was dramatic changes in the weather patterns like reduced snowfall and its changed timing [34]. Research conducted in 2013 stated that the fruit growers in Kotgarh area of Shimla District perceived similar changes in snowfall pattern, with rare incidence of snowfall in December and January and prolonged winters extending through the months of February-March supports the present study [35].

Trend analysis indicated that snowfall is decreasing in the study area, which finds the support of observation made by researchers in 2014, who reported the decrease in snowfall at the rate of 82.7 mm/annum in Himachal Pradesh [36]. Thus, because of unsuitable climate, the apple cultivation area is shifting to higher elevation, which is abruptly affecting the production trend. Similar finding were reported by researchers in 2009, who described an overall decrease of about 2-3% in yield in Shimla, Kullu and Lahaul and Spiti districts in 2000s. Apple cultivation areas in lower elevations like Solan have been reported to be reduced [37]. Thus the finding of study is in agreement with the observations made by researchers in 2013, who reported the reduction in area by as much as 77% between 1981 and 2007 [38].

IV. CONCLUSION

Thus, in order to face the threats posed by climate change there is need of identifying and evolving successful adaptation strategies for sustaining apple cultivation. The need of the hour is to:

- Develop impact assessment plan;
- Assess vulnerability and identify long-term plans;
- Develop region-specific forecasting tools that can be used at the time of need;
- Switch over to crop diversification;
- Develop resistant genotypes;
- Evolve best agronomic management strategies;
- Use biotechnological innovation strategies;
- Undertake mapping of climate resilient and climatically venerable niche in apple cultivation belts;
- Monitor phenological changes under changing climatic conditions; and
- Revive indigenous methods of crop protection, retaining of moisture content in soil and maintaining of soil fertility

V. ACKNOWLEDGEMENT

The authors acknowledge the Directorate of Horticulture, H. P. Shimla, Dr. Y. S. Parmar University of Horticulture and Forestry, Nauni, Meteorological Department and H. P. University for providing the data.

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