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IMPACT OF CLIMATE CHANGE ON APPLE PRODUCTIVITY IN HIMACHAL PRADESH-INDIA

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Abstract *Impact of climate change on apple productivity has been studied through water resource availability, linkages among weather parameters and suggesting remedial measures for growth of apple output by adopting functional and statistical tools. Results reveal average annual rain and snowfall as 121.9 cm and 96.5 cm. Albeit rainfall (121.9 cm) has been found within the required range (100-125cm) for good apple production, yet productivity has shown huge differential (1 to 53 kg/tree) due to non availability of water at critical stages of at first dormant stage followed by other critical stages of growth. 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. Mean difference in annual maximum temperature has been worked out to be 24.41 per cent indicating 'warming up of the eco system'. This temperature variation has disturbed the timely availability of water simultaneously accompanied by changes in other parameters thereby cumulatively bringing apple production range between 2-110 ton/ha. Thus, functional analysis of weather parameters have revealed that availability of weather factors within the critical limits of growth stages has been found to be a 'must' otherwise drastic fluctuations in productivity have been reported. Hence, integrated efforts in water resource developmental projects through creation of vegetative cover have been considered as the best for improving water availability for enhancing apple productivity*.

1. INTRODUCTION

Natural resources specifically land and water amongst others make all technologies viable in the field of agriculture and this has social and economic consequences leading to cause and effect relationships. Himachal Pradesh located between 30°22' and 33°12' N latitude and 75°47' and 79°4' East longitude comprising of 4 agro-climatic zones with an altitude range 350 to 7000 meters above mean sea level receives 18 to 300 cm of rain fall (Anonymous, 2007). This State has a natural advantage of growing variety of fruit crops due to its location and thereby prevailing agro-climatic conditions. Amongst different fruits grown apple occupies the dominant shares with respect to area (about 47 per cent of the total area under fruits) as well as production (about 83 per cent of total fruit production, Anonymous, 2008). Fruits' production in general and apple production in specific, accompanied by marketing processes as well as other supplementary activities to fruits' production, have been playing a vital role in improving the socio-economic conditions of all the concerned agencies by creating employment and generating income..

Apple industry is well established and dynamic in character. As a result of various research and development efforts, new technologies like new varieties have been replacing the old ones and new critical inputs have been entering into production of apple. More so, the innovative fruits' growers have also been evolving new management practices and strategies in response to emerging needs. The over all growth of apple industry in the State over a period of time has not been found to be dependent on man made factors only. Natural factors which are uncontrollable have huge impact in bringing significant variations in production of fruits in general and apple in specific. As the crop output is a combination of both controllable and uncontrollable factors, so 'productivity of crops' can be adjudged in the best way if all the factors are taken into consideration. Albeit productivity concept has been explained through quantifiable controllable factors in various studies, yet this paper has been developed to find out impact of climatic change on apple productivity through specifically water resource availability to the crop inter alia interaction amongst other weather parameters like temperature, rainfall, snowfall, hails, humidity and evaporation.

2. OBJECTIVES

This paper has been developed with the following specific objectives:

(i) To study the extent of variation in water resource availability in the orchards.
(ii) To identify linkages amongst weather parameters affecting apple productivity and
(iii) To suggest remedial measures for planned and balanced growth of resources and apple output.

3. MATERIALS AND METHODS

Primary and secondary data have been collected for Shimla district of Himachal Pradesh by adopting purposive and multi-stage stratified random sampling. The size of sample has been kept 100 for primary data and time series data covers a period of 2 decades i.e., 1988-89 to 2007-08. Primary data have been collected on controllable factors like number of plants, farm yard manure and fertilizers and insecticides and pesticides use by the fruit growers along with uncontrollable factors like temperature, rain fall, snow fall , humidity, hails and evaporation etc. for the period 2006-07 and time series data on production of 6 cultivars of apple namely Royal Delicious, Top Red, Vance Delicious, Skyline supreme, Hardeman and Red Spur covering about 58 per cent of the total population of different varietal set up of high density plantations at the research station (Anonymous, 1988 to 2008) along with data on uncontrollable factors for 2 decades (Anonymous, 2005). Data were analyzed by calculating weighted averages, multiple responses and by using Cobb Douglas and Quadratic form of production functions of the form:

(i) $Y = b_o X^{i\ bi}$ where, Y = Total physical production of 6 cultivars of apple and X_{is} are independent uncontrollable variables where i runs from 1 to 8 as X_1 maximum temperature, X_2 minimum temperature, X_3 Rainfall, X_4 Snowfall, X_5 Hails, X_6 Humidity (morning), X_7 Humidity (evening) and X_8 Evaporation. (ii)$Y = b_o + b_1 X_i +/- b_2 X_i^{2.}$ Flow diagram based on logical method of analysis has been used to inter link weather parameters to water availability: Temperature (Land and Water) → Rainfall/Snowfall/hails → Evaporation → Humidity.

4. RESULTS AND DISCUSSIONS

Results and discussions can be explained under the following sub-headings

4.1 VARIATIONS IN WATER RESOURCE AVAILABILITY

Nature has never been so miser in fulfilling the requirements of living beings and all other users of it's invaluable resources. Howsoever, our deeds/greed and programs on the path of development if not in harmony with the complete cycle of natural events, show unwillingness of nature to bless us with it's resources in adequate quantities at the required period of time. Consequently, a situation of 'scarcity' is created due to imbalance in demand for resource and it's supply with respect to time of it's availability and use.

'Water' is the most essential input in bio-world has relatively been becoming ore and more scarce with an increasing number of it's users and uses. Per capita availability of water has declined by about 65 per cent in India during last about five and a half decade (Anonymous, 2007). There is no absolute scarcity of water, only the relative scarcity exists due to improper management practices while putting water to various uses. Although, Himachal Pradesh receives on the average about 180 to 3000 mm of rainfall, yet scarcity of water exists in the State. The climatic conditions in Shimla district vary from the temperate to the alpine with low lying areas experiencing warm season. As a result, the crop cultivation varies according to location and altitude of the area. The average annual rainfall and snowfall in Shimla district have been found to be 121.9 cm and 96.5 cm respectively during the last two decades (Table 1). The average rainfall of about 100-125 cm on per annum basis provided it is distributed evenly through out the year has been found to be the best for good production of apple (Anonymous, 2009) but even distribution of rains has not been found possible because of about 70 per cent of total rainfall on per annum basis is precipitated during rainy season and remaining 30 per cent during spring, winter and autumn seasons. An economic analysis of rainfall data for two decades has shown the total requirement of rains on per annum basis lying between the required range of 100-125 cm for 9 years out of 20, i.e., for about 45 per cent of the total period of rain fall yet the apple productivity has shown huge differential due to uneven distribution of rains for more than half the total period under study.

Table 1. Total Rainfall and Snowfall at Regional Horticultural Research Station, Mashobra, Shimla during 1988-89 to 2007-08.

Sr. No	Particulars	Rainfall (cm)	Snowfall (cm)
1.	Average on per annum basis	121.9	96.5
2.	Required range for good apple production	100 - 125	-
3.	During the study period (1988-89 to 2007-08) i.e., in a period of 20 years : In 3 years In 8 years In remaining 9 years	Less than lower limit of the required range i.e., 100 cm More than the upper rangeof the required range i.e.125 cm Within the required range i.e., 100 - 125 cm	-

4.2. Weather Parameters and Apple Productivity

4.2.1 Growth Stages, Rainfall and Snow Fall

In order to analyze the apple productivity in relation to weather parameters, growth in apple crop has been divided into 4 growth stages namely (i) Dormant stage from December to March (ii) Flowering and fruit set stage from April to May (iii) Growth and development stage from June to September and (iv) Pre dormant stage from October to November. It has been found that each stage has been observed to be having specific requirements of weather parameters i.e., specific range of maximum and minimum temperatures, rainfall, snowfall, humidity and evaporation for uniform growth and development of vegetative and reproductive parts of the apple plant. Table 2 shows range of mean rainfall - each growth stage-wise as well as range of total months' rainfall in each stage along with the snow fall during the study period. It can be inferred from the time series information of rainfall that instead of even requirement of availability of 10.0 to 12.5 cm of rains on per month basis for good production of apple crop, the crop has to face a period in at least 3 out of 4 stages when rainfall has been found to be below the lower limit i.e., 10.0 cm and in all four stages upper limit has been exceeding the limit of necessarily required rains on per month basis. Hence, either lesser or greater availability of water on per month basis in each growth stage has been found to disturb the uniform growth pattern of all the varieties of the apple crop leading thereby to productivity differential (about 1 to 53.3 kg/tree). The water availability has been found to be deficit during 75 per cent of the total time period of different stages of growth leading thereby to varying apple production.

Although range of total snow fall during the dormant stage has been found to be 26.1 and 164 cm, yet during the critical months of this stage when snow fall has been considered to be essentially required for undertaking winter operations most importantly application of fertilizers no snow fall has been reported for about half (about 52 per cent) of the period of growth.

4.2.2 Temperature

Apple being a perennial crop yields one total harvest in a year, thus different resources like land, labor, capital and management in the orchards are put to use during this period of one year to complete one production cycle. Present year 'picking' of apple crop ends the present year production cycle and initiates the production process for the next year. To analyze critically the effect of weather parameters on apple productivity, role of different parameters like maximum and minimum temperatures, rainfall, snowfall, hails, humidity and evaporation has been considered to be of utmost importance that too during critical periods of each stage. Amongst all the parameters 'temperature' has been found to be the 'pivotal factor' which has been found controlling the intensity of occurrence of other weather parameters through controlling hydrological cycle in micro as well as macro locations. Time series data have

Table 2 Growth stages-wise and specified months in each stage - wise ranges of total rainfall and snow fall during the study period (1988-89 to 2007-08).

Sr. No.	Growth stage/s	Period	Range of total rainfall during the study period	Range of total rainfall during the specified months in each stage	Range of total snow fall	Range of Total snowfall during the specified month/stage
1.	Dormant	December to March	9.5 – 29.5	3.2 – 17.1	26.1 - 164	0 – 117.9
2.	Flowering and Fruit set	April - May	4.3 – 27.1	0 – 15.1	0 - 0	0 - 0
3.	Growth and development	June - September	56.4 – 143.1	12.0 – 57.7	0 - 0	0 - 0
4.	Pre dormant	October - November	0.2 – 13.1	0 – 12.7	2.0 – 4.80	0 – 4.8
	Average rains available/annum	Jan - Dec	121.9	-	-	-
	Necessarily required for good apple production		100-125 cm evenly distributed through out the year	10.0 – 12.5	-	-

revealed the over all difference in the range of annual maximum temperature to the tune of about 24.41 per cent during the previous two decades, which clearly indicates warming up of the eco-system' with the passage of time, whereas, stage- wise variations in mean maximum 'temperature have been worked out to be about 12 to 54 per cent during the previous two decades as shown in Table-3. This variation has been found to be maximum at dormant stage and minimum at growth and development stage whereas the required variation should have been more from lower limit side for driving the temperature to the minimum range of the chilling requirement during this stage. In other words, required variation should have been 'reverse' from upper limit side for meeting out the chilling requirements and proper growth of fruits during growth and development stage. This reverse trend in maximum temperature has been observed to be one of the factors responsible for productivity differentials.

Similarly, although the minimum temperature range, on the average, has been found to be 7^o or below 7^oC, yet during the four months in the dormant stage upper limit of the range has been found to be greater than 7^oC which has not made a chain of chilling hours possible accompanied by lower rainfall and snow fall than the required quantum.

4.2.3 Hails

Albeit hails add to water potential of the soil yet spoil the quality as well as quantity of the fruit. It depends upon the stage during which hails occur. The hails occurrence has been reported in number of times which ranged between 1 – 9 times in a single season during the study period. At the flowering and fruit set stage, the hails accompanied by other variable weather factors during 1998-99 and 1999-2000 dropped the yields to the minimum, whereas quality of the crop have been found affected during the stage of growth and development in 2004-2005 although the yield level was satisfactory.

4.2.4 Humidity

Data have revealed that more temperature in general has lead to more evaporation and humidity which lead to comparatively lower yields than the lesser humid years. Range of morning humidity and evening humidity has been found to be 18 - 63 and 5-60 per cent respectively. Yield have generally been found to be higher with 50 – 60 per cent of humidity range.

Table 3. Range of mean maximum and minimum temperatures - stage wise and the specified months in each stage.

Sr. No.	Stage/s	Range of Mean maximum temperature during each stage	Range of maximum temperature during specified months/stage	Range of Mean minimum temperature during each stage	Range of minimum temperature during specified months/stage
1.	Dormant	10.5° – 16.2°C (54.00)	8.1° – 19.2°C	0.9 – 5.5°C	-1.46 – 15.7°C
2.	Flowering and fruit set	21.0° – 28.0°C (33.00)	17.4° – 26.6° C	8.3° – 15.2°C	7.2° – 19.2°C
3.	Growth and development	21.1° – 28.7°C (12.00)	21.0° – 28.7°C	12.1° – 17.3°C	10.2° – 17.7°C
4.	Pre dormant	15.0 -22.4°C (49.00)	13.2° – 28.1°C	5.6° – 9.0°C	3.8° – 10.0°C
	Required range		23°-27.0°C		7° or less than 7°C

4.3 Linkage Between Apple Productivity and Weather Parameters

4.3.1 Rainfall, Snow Fall and Temperature – A Cumulative Effect on Apple Productivity

Lower temperature specifically at dormant stage (7° or below 7°C) accompanied by rains and timely snow has been found to be quite irregular at least for 3 months during the dormant stage as a result flowering and fruit set has not been good thus provided poor yields during these months. Month wise data has revealed poor rains during first three months of the dormant stage which has brought drastic fluctuations, yielding as low as 1 kg/tree in 1999-00, 1.707 kg/tree in 1993-94 and 1.766 kg/tree in 1989-90 whereas 20-50 per cent of the required rains during the dormant stage in first three months i.e., from December to February has brought significantly higher yields, as high as 53 kg/tree in 2007-08.

During growth stage II termed as flowering and fruit set stage, for at least half the period (about 50 per cent) of study, maximum temperature has been found to be favorable for proper flowering and fruit set thereby yielding better than the worse years.

Temperature conditions during stage III termed as growth and development stage have been conducive ranging between 21.1 to 23.6°C during the study period, but this temperature range accompanied by rainfall yielded good apple production.

Analysis of linkage between apple productivity and weather parameters has revealed the temperature variations due to disproportionate growth of man made assets as pivotal factor in disturbing hydrological cycle through causing variations in other parameters like evaporation, humidity, rainfall, snowfall and hails. Individually each weather parameter has been found affecting apple productivity in each of its 4 growth stages. Thus, apple productivity depends upon even minor variations in any of the parameters which have shown abrupt changes in productivity if such variations occur at critical stages of growth. In other words, it can be inferred that variations in apple production ranging between 0 to almost 100 per cent among different cultivars of apple during the period under study have been due to the cumulative effect of variations in weather parameters during the four growth stages. Although temperature has been the major cause of disturbing hydrological cycle yet in physical units it is the quantum of water available for use by the plant during critical stages of growth which have been found affecting positively or negatively the apple productivity.

4.3.2 Impact of Weather Parameters/uncontrollable Factors on Apple Productivity

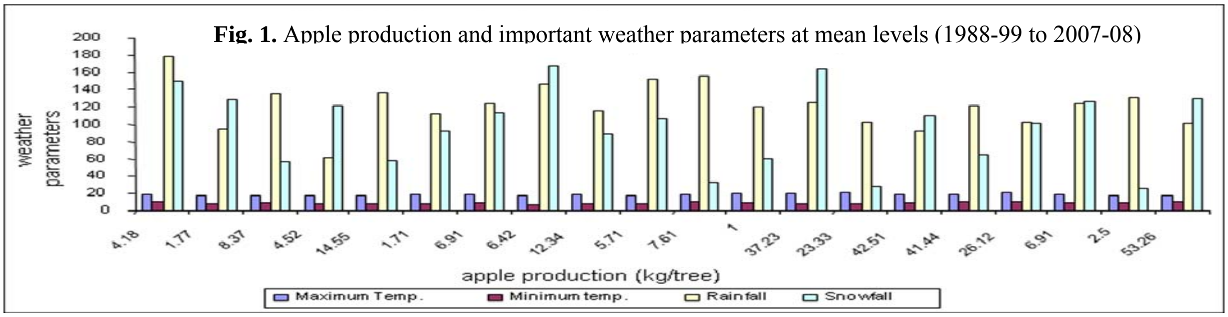
Weather parameters have been considered uncontrollable as these have been found to be controlled by nature only but these can be managed to certain limits by man, therefore can be termed as manageable. In order to quantify changes in apple production on account of additional unit change in either of the uncontrollable factors most importantly maximum and minimum temperatures, rainfall and snowfall etc. , the primary and time series data were subjected to non-linear form of regression.

In case of primary data, although results in relation to weather parameters were found to be theoretically plausible yet statistical significance could not be established excepting minimum temperature (0.031), humidity (-0.032) and rainfall

(0.042) (Randev, 2008). Similarly, the step wise results have shown significance in case of maximum temperature (-0.021), snowfall (0.048) and evaporation (0.011).

Apple production and weather parameters, most importantly maximum temperature, minimum temperature, rainfall and snowfall for complete time series data at arithmetic mean levels have been shown in Fig. 1 which

Fig. 1. Apple production and important weather parameters at mean levels (1988-99 to 2007-08)



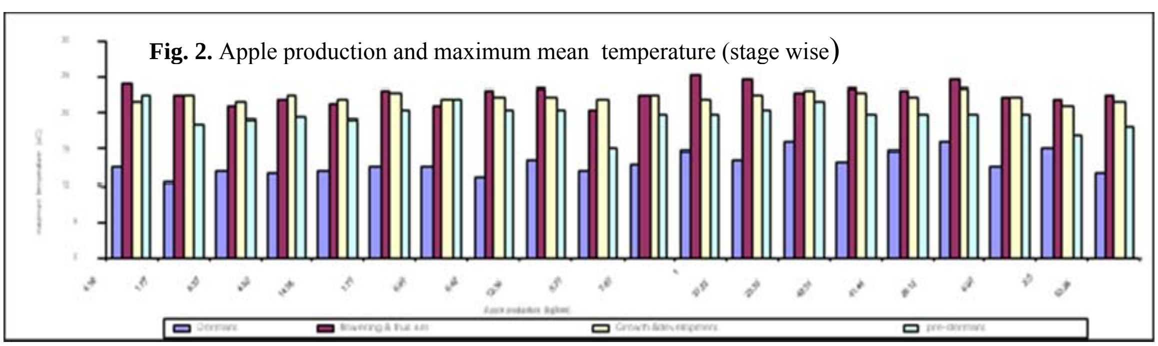
In relation to maximum temperature, $Y = -0.008x^2+0.227x+17.636$; $R^2 = 0.19$: *minimum temperature,* $Y = 0.012x^2-0.189x+8.975$; $R^2 = 0.29$: *rainfall,* $Y= -0.048x^2+0.201x+126.76$; $R^2 = 0.04$: *snowfall,* $Y= 0.233X^2-6.300x+129.31$; $R^2 = 0.063$

have shown quadratic behavior in case of maximum temperature and rainfall, indicating diminishing rate of physical production with an increase of an additional unit of temperature as well as rain fall leading to an important inference that after a certain limit of either of the variables decline in production starts. Similarly, in case of minimum temperature and snow fall function indicates that after a certain minimum, there has been a positive relationship between minimum temperature and snow fall with apple production.

In case of time series data too statistical significance could not be established for either of weather parameters but quadratic analysis of apple production with respect to specified weather parameters has only revealed the trend the weather parameters have been behaving with production as shown in Fig. 2, 3, 4 and 5.

Fig. 2 has revealed diminishing rate in apple production with an additional unit rise in temperature means at optimum maximum temperature the apple production will be maximum because of diminishing rate. Fig. 3 reveals that after a certain minimum temperature at each stage, there has been a positive relationship between minimum temperature and apple production. Fig. 4 has revealed maximum variation (81 per cent) in apple production with available total rainfall during growth and development stage. Fig. 5 reveals the direct relationship between apple production and snow fall after a certain limit. One thing is common in the relationship between apple production and each weather parameter separately that the kink after attaining maximum production with respect to say temperature starts declining indicating thereby that after a certain limit of weather parameter it starts adverse impact on the production potential of apple plant. Consequently, production on per tree basis starts diminishing.

Fig. 2. Apple production and maximum mean temperature (stage wise)



In relation to maximum temperature at dormant stage, $Y = -0.011x^2+0.378x+10.573$; $R^2 = 0.38$: *at flowering and fruit set,,* $Y = -0.005x^2 -0.155x+21.889$; $R^2 = 0.60$: *at growth and development stage,* $Y= -0.009x^2+0.193x+21.467$; $R^2 = 0.20$: *at pre dormant stage, ,* $Y= -0.006X^2+0.046x+19.946$; $R^2 = 0.09$

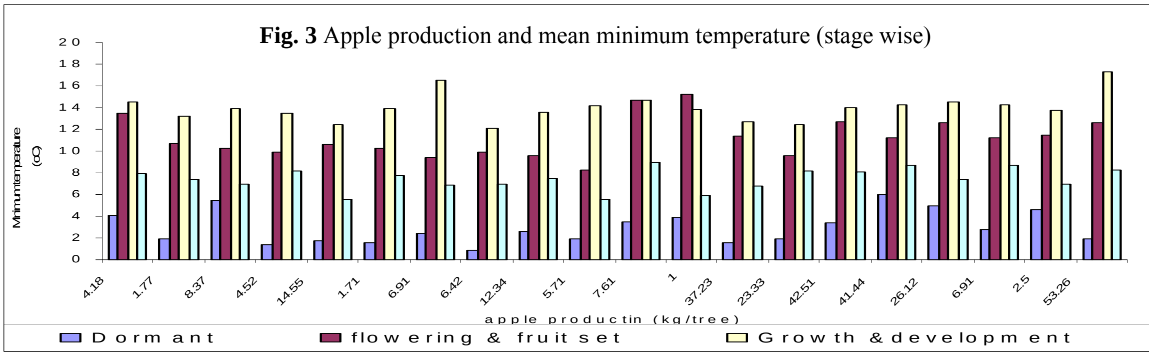


Fig. 3 Apple production and mean minimum temperature (stage wise)

In relation to maximum temperature at dormant stage, $Y = 0.012x^2-0.200x+3.256$; $R^2 = 0.121$: at flowering and fruit set,, $Y = 0.011x^2 -0.141x+11.236$; $R^2 = 0.10$: at growth and development stage, $Y= 0.014x^2-0.22x+14.412$; $R^2 = 0.19$: at pre dormant stage, , $Y= 0.009X^2-0.136x+7.633$; $R^2 = 0.14$

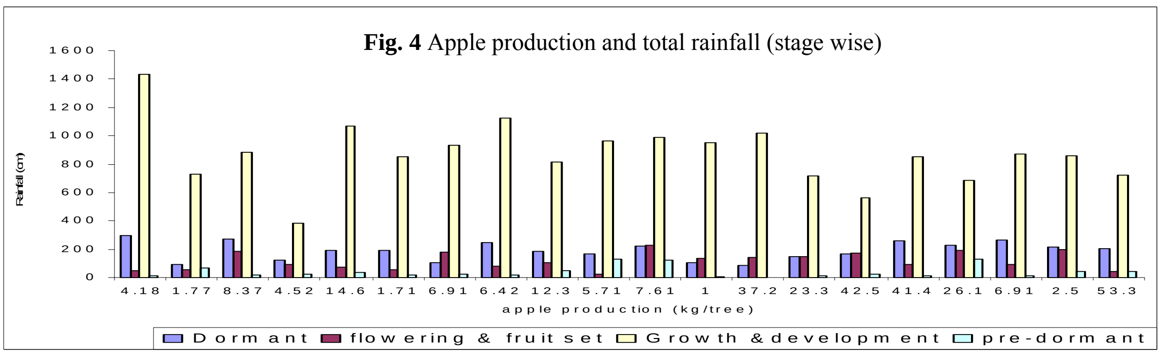


Fig. 4 Apple production and total rainfall (stage wise)

In relation to maximum temperature at dormant stage, $Y =0.789x^2-15.553x+283.16$; $R^2 = 0.15$: at flowering and fruit set, $Y = -0.465x^2-12.616x+51.867$; $R^2 = 0.13$: at growth and development stage, $Y= -0.091x^2-8.8650x+974.61$; $R^2 = 0.81$: at pre dormant stage, $Y= -0.153X^2+3.881x+22.002$; $R^2 = 0.02$

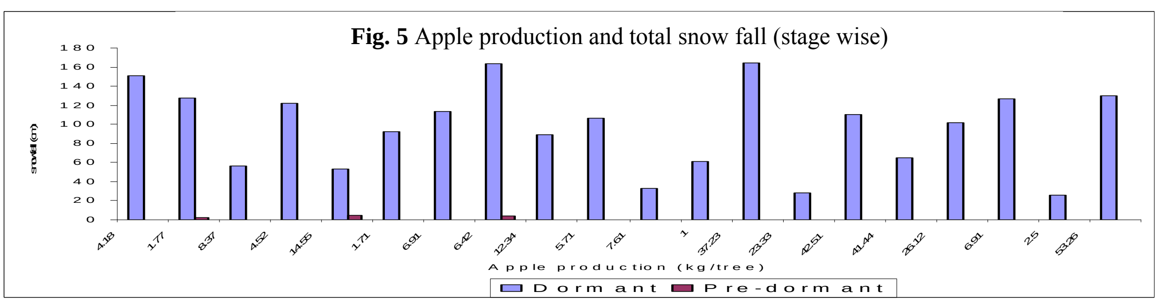


Fig. 5 Apple production and total snow fall (stage wise)

In relation to maximum temperature at dormant stage, $Y = 0.235x^2-6.279x+128.14$; $R^2 = 0.06$, and at pre dormant stage, $Y= -0.002X^2-0.018x+1.238$; $R^2 = 0.12$.

Consequently, it has been found that range of each weather input within the critical time limits of each stage, accompanied by orchard management practices on scientific lines, can enhance the apple productivity to the maximum. This has only been due to the fact as has been revealed by the analysis that availability of water, within the critical limits of time frame like time of application of fertilizers, before flowering and during growth of fruits etc., has been found to be ‘a must’ for higher yields, otherwise huge variations in apple productivity have been found in spite of minor variations in total rainfall or water available on per annum basis.

5. REMEDIAL MEASURES FOR PLANNED AND BALANCED GROWTH OF RESOURCES AND APPLE PRODUCTIVITY

The climate change has invariably been an outcome of unplanned way of capital formation. The need of the hour is to integrate the developmental efforts in such a way that the environmental hazards are minimized. This requires integrated efforts for a common cause by involving technical services of multidisciplinary experts so as to have least negative impacts of the program/project.

Apple production as any other output has been the consequence of action and interactions of a number of inputs. The role of specified weather parameters, keeping use of controllable factors constant, has been observed to bring huge variations in productivity, therefore, it has been inferred that in micro locations/eco systems based on apple production activity, an integrated effort is required at least to make water available to the growers.

5.1 Holistic Approach in Planning Developmental Activities

Water can only be made available only if 'nature' blesses us with timely rains and this demands the regularization of the hydrological cycle. Single micro location may not be effective in putting impact on this cycle, but combination of hundreds of micro locations definitely going to pay dividends. To enter into the basis of hydrological cycle, naked lands need to be covered with vegetation through forming a cycle of rains, conservation of water to be used during deficit period and thus keeping land covered with either of the crops through out the year. The vegetation cover has been found responsible for maintaining evaporation, humidity and temperature.

The temperature changes during the critical period of each growth stage of apple crop accompanied by availability of water resource at that period of time can sustain apple productivity, therefore, in micro eco systems, vegetative cover maintaining temperature along with water harvesting structures constructed for utilizing stored water during critical stages of growth can minimize productivity differential. Integrated planning, thus in all those developmental activities which have direct or indirect effect on vegetative cover and water resource like road construction, forestation and other all agriculture related activities with emphasis on water conservation practices must go side by side with scientific planning. It needs emphasis that water resource related development projects require seriousness in planning and implementation with joint efforts of all the experts required for the purpose.

6. CONCLUSIONS

1. Natural factors albeit uncontrollable yet manageable have huge impact in bringing significant variations in apple productivity (0 to 100 per cent).
2. There has been no absolute scarcity of water, only the relative scarcity exists due to improper management practices while putting water to various uses.
3. Albeit total rainfall on per annum basis (121.5 cm.) has been reported to lie within the specified required range (100 -125 cm/annum but with even distribution through out the year), yet huge apple productivity differential has been found due to uneven distribution of rains in a year thereby non availability of water during the critical limits of different growth stages of apple crop.
4. Rainfall for more than half the period of 20 years (52 per cent) has been reported to be either less than or greater than the upper limit of required range and that too beyond the critical limits has been found resulting irregular supply of water to the orchards bringing variations in apple productivity (1 to 53.3kg/tree).
5. Amongst all the weather parameters, 'temperature' has been found to be the pivotal factor, controlling the intensity of occurrence of other parameters through controlling the hydrological cycle in micro as well as macro locations. Over all difference in the range of annual maximum temperature has been found to about 24.41 per cent during the previous two decades indicating 'warming up of the eco systems' resulting further growth-stages wise adverse variations thereby disturbing chilling requirements as well as flowering and fruit set and growth and development stages.
6. Lower temperature specifically at dormant stage (7o or less than 7o for 1000 to 1600 hrs.) accompanied by rains and snow has been found to be quite irregular for 3 months during the dormant period as a result flowering and fruit set has not been good thus leading to poor yields.

7. Month-wise data have revealed poor rains during first three months in the dormant stage which has brought drastic fluctuations, yielding as low as 1 kg./tree during 1999-00, 1.707 kg/tree in 1993-94 and 1.766 kg/tree in 1989-90, whereas 20-50 per cent of the required rains during the dormant stage during the same period has brought significantly higher yields – as high as 53.3 kg/tree in 2007-08.

8. Good apple production has been reported during the periods when favorable or required temperature during the growth and development stage (stage III) was accompanied by rains.

9. Hails' occurrence has been reported varying productivity between 0 to 100 per cent depending upon the frequency, simultaneously affecting quality of the produce.

10. Humidity range between 50 – 60 per cent has been found yielding higher levels of production.

11. Over all variations in apple productivity have been found due to 'cumulative effect' of variations in weather parameters during four growth stages of the apple crop. Although temperature has been the major cause of disturbing hydrological cycle yet in physical units, it has been the quantum of water available for use by the plant during critical stages of growth which have been affecting either positively or negatively the apple productivity.

12. Although the results in relation to weather parameters in case of primary data were found to be theoretically plausible yet statistical significance could not be established excepting minimum temperature (0.031), humidity (-0.032) and rainfall (0.042). In case of time series data quadratic behavior has also shown the final apple output as per the variations in weather parameters during critical stages of production cycle.

13. Integrated planning involving multi-disciplinary experts have to be adopted for formulating and implementing water related development projects in production areas. Seriousness and scientific action oriented approach has been observed to be the best solution in minimizing the apple productivity differential.

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