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Impact of Changing Climate on Apple Productivity

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ABSTRACT

The productivity of temperate fruits especially apple in Himachal Pradesh is declining at a faster rate. Average yield of apple in India has been estimated at about 7.0 tonnes per hectare which is far below the level of 30 tonnes per hectare in most of advanced countries. The productivity has also not kept pace with the expansion in area under temperate fruits due to various biotic and abiotic problems faced by the farmers in the Himalayas. This has caused a serious concern not only to the hill farmer community but also to researchers, development agencies and policy planners. With the global warming, the decline in productivity is being mainly attributed to changing climatic scenario. It is clearly reflected that standard apple cultivar Starking Delicious and Red Delicious would not flower and fruit when chilling units are not adequately fulfill. Hence there is an urgent need to select appropriate low chill cultivars for plantation at low elevation location so that consistent yields are obtained and crop failures avoided. To meet the bulk requirements of the processing units and horticultural diversification, apple cultivation can be extended to mid hills by planting suitable low chilling cultivars. The low productivity of apple has become a serious concern for the farmers, research workers and development agencies at national and state level for the last two decades. Several factors can be attributed to the declining trend in productivity like expansion of apple cultivation to marginal areas, monoculture of Delicious varieties, declining standards of orchard management, improper chilling requirements and the fluctuating abnormal climatic conditions.

Key words:

Apple, bud break, chill units, cultivars

INTRODUCTION

The low productivity of apple has become a serious concern for the farmers, research workers and development agencies at national and state level for the last two decades. Several factors can be attributed to the declining trend in productivity like expansion of apple cultivation to marginal areas, monoculture of Delicious varieties, declining standards of orchard management and the fluctuating abnormal climatic conditions. Average yield of apple in India has been estimated at about 6 tonnes per hectare which is far below the level of 30 tonnes per hectare in most of advanced countries. The productivity has also not kept pace with the expansion in area under temperate fruits due to various biotic and abiotic problems faced by the farmers in the Himalayas. This has caused a serious concern not only to the hill farmer community but also to researchers, development agencies and policy planners. With the global warming, the decline in productivity is being mainly attributed to changing climatic scenario.

In Himachal Pradesh, apple is, grown commercially from 1 ,524 to 2,472 m above mean sea level (amsl) and has played, an important role in boosting the economic status of the farmers. It accounts for about 85 percent of the total fruit production of the state. In spite of increased production, there is a big gap between the area under apple and its productivity. Moreover, in last two decades there has been a ups and downs in apple productivity from 10.84 t ha^{-1} in 1981-82 to 6.35 t ha^{-1} in 2003-04 and in 1999-2000, it was, even as low as 0.82 t ha^{-1} but 10.82 t ha^{-1} again in 2003 and low in 2010 and again rise in 2012(10.01 t/ha). In India, better soil and weather conditions prevail in Himalayan foot hill that are conducive for growing low chilling varieties of fruits like pear, plum, peach etc. Researchers over more than two decades have evolved and tested number of low chill cultivars of apple fruit (Sharma and Karkara 2004; Kuden and Kuden 2004; Bal 2004; Sharma et al. 2004) in India.

The area in and around Shimla in Himachal Pradesh (India), is strictly not a temperate zone region, however, because of its altitude (1900 – 2600 m ASL) it is able to support a fairly good production of temperate pome and stone fruits. Erratic winter chilling in some apple growing areas of late has raised alarming concerns about the continued sustenance of productivity of temperate fruits, particularly of apple, in the region. It will be pertinent to determine the extent of climate change in the region and its impact on productivity of apple trees.

A number of models have been developed for calculating or estimating chilling/ chill units accumulated during winter months in a particular area (Allan 1999; Erez and Fishman 1998; Linsley-Noakes et al. 1995; Linvill, 1990; Richardson et al. 1974; Shallout and Unrath 1983; Fishman et al. 1987a, b).

In the present paper, an attempt has been made to study the influence of changing climate, a major limiting factor of temperate fruits production especially apple and to analyze the main climatic variables in relation to apple productivity (Anon., 2004).

MATERIAL AND METHODS

The present investigations were carried out during last one decade at experimental farm of Indian Agricultural Research Institute, Regional Station, Shimla, India on 9 (nine) apple cultivars namely, Anna, McIntosh, Michal, Parlin's Beauty , Red Delicious, Red June, Schlomit, Tamma and Tropical Beauty. The plants under evaluation were 10 years old having uniform size, raised on seedling rootstock planted in a Randomized Block Design with five replications. Data was recorded on various characters (Table 1) and analyzed as described by Panse and Sukhatme (1995).

Tree volume was calculated as methodology suggested by Westwood (1978). Coefficients of variability were calculated as per the formula suggested by Burton and DeVane (1953). Positive Chill Unit (PSU) accumulation and Chilling Portion (DM) accumulation was obtained as described by Linsley-Noakes et al. (1995) and Anonymous (2012), respectively.

Weather data were collected from the two automatic weather stations installed at two locations in the different research farm of the IARI Regional Station, Shimla. These locations were at variance from each other with respect to their micro-climates due to different aspects (Northern and Southern) as well as altitude. Data were also collected from the agro-meteorological section of the Central Potato Research Institute, Shimla. Positive Chill Unit (PSU) accumulation and Chilling Portion (DM) accumulation was obtained as described by Linsley-Noakes et al. (1995) and Anonymous (2012) respectively.

The chilling units on a daily basis were ascertained from the hourly temperature data on the basis of the conclusions drawn from the Utah Model (Richardson et al. 1974; Table 2).

Controlled conditions experiment was conducted to study the effect of chilling units on bud break. The potted plants of Starking Delicious apple were subjected to 500, 750, 1000, 1250 and 1500 chill units in a cold chamber maintained at 6° ± 2°C with 8 h light and 16 h dark. After the treatments with specific chilling, the plants were transferred to a growth chamber maintained at 18° ± 2°C to record the response to bud break.

RESULTS AND DISCUSSIONS

Data on the mean value of various plant growth, floral behaviour and fruit characters are presented in Table 1. The plant height values varied from 4.15 m (Anna) to 5.85 m (Tropical Beauty) and both differed from one another statistically. The values for other cultivars also showed marked variation. Cultivar, Tropical Beauty also scored maximum trunk girth (59.80 cm) and tree volume (73.80 m^3), whereas lowest values for these traits were recorded for McIntosh (37.70 cm, 29.70 m^3), respectively. Minimum shoot length was recorded for Red Delicious (21.45 cm) followed by Red June (22.40 cm) though similar statistically.

In cultivar Tropical Beauty, maximum shoot growth (31.50 cm), followed by McIntosh (29.85 cm). Leaf area a growth determining factor varied from 33.22-42.50 cm^2. Cultivar Parlin's Beauty registered minimum value (33.22 cm^2), while Tropical Beauty (42.50 cm^2) outscored other cultivars for this trait.

The observations pertaining to floral triats were recorded on days from bud burst to first flower opening, first flower opening to full bloom and number of flowers/unit of shoot length. Days from bud burst to first flower open where minimum for Red Delicious (8.30), followed by Parlin's Beauty (9.60) and both values were similar statistically, while 'Schlomit' and 'Anna' took 14.50 and 12.50 days respectively. Cultivar 'Schlomit' (10.98) followed by 'Anna' (10.30) recorded maximum days from first flower open to full bloom, whereas 'Tamma' and 'Tropical Beauty' accomplished this event in minimum time period of 7.1 and 7.6 days respectively. Cultivar Tropical Beauty (32.15) and Parlin's Beauty (29.95) statistically produced same number of flowers per unit shoot length and showed no variation, while 'Tamma' (15.0) and 'Red June' (16.10) had less flower number (Sharma et al.2004; Gautam and Chauhan 1986; Subhadrabandhu and Watanawong 1990).

Fruit traits are the ultimate deciding factors that determine variation and its adoption by the orchardists. In the present study fruit yield per plant varied from 20.80 to 38.90 kg per plant. Cultivars Tamma (20.80 kg $plant^{-1}$) followed by McIntosh and Red June produced lower yield of 23.50 kg per tree and these cultivars differed from each other. Higher yield were observed for cultivars Tropical Beauty (38.90 kg $plant^{-1}$) followed by Michel (33.60 kg $plant^{-1}$) and Anna (28.80 kg $plant^{-1}$). Mean fruit weight ranged from 66.60 g in 'Red June' to 130.20 g in Tropical Beauty. Other cultivars also showed inherent genetic variation. Cultivars Red June, although registered lower values of other fruit traits but had maximum value of TSS content of 12.35°Brix, followed by Red Delicious (12.10°Brix) and minimum content was observed in Schlomit (9.50°Brix), titrable acidity ranged from 0.23 percent in Anna to 0.79 percent in 'Tamma' and both differed statistically. The trait total sugar varied from 4.75-8.20 percent, maximum value being obtained for Tropical Beauty, followed by Parlin's Beauty (6.85%), while Anna had minimum (4.75 %) total sugar content.

Perusal of the total chill units received in Shimla, H.P, India during the last five years of the study show that in none of the years the accumulation was less than 1000 chill units. This is well within the range for cultivation of apples. However, the year to year fluctuations are a matter of concern and a further long term study should be continued to fully understand the impact of global warming on chilling units' accumulation at Shimla, Himachal Pradesh.

Standard delicious apple trees were grown at two locations, an ideal site (2286 m amsl) and the marginal site (1375m amsl), designated as location A and B respectively. The temperature and full bloom data was recorded for both the sites (Jindal and Mankotia 2004; Mankotia et al. 2004). Two techniques were used to compare the chilling requirement of Starking Delicious apple- i) accumulation of chilling hours below 7.2oC ii) determination of effective chill units to break the rest period by adopting Utah Model (Richardson et al. 1974; Ashcroft et al. 1977; Kishore et al. 2014).

Table 1: Mean values for various growth and yield characters in apples

	Anna	Mc Intosh	Michel	Parlin Beauty	Red Delicious	Red June	Schlomit	Tamma	Tropical Beauty	$CD_{0.05}$
Plant height(m)	4.15 **3.70**	4.70 **4.59**	4.50 **4.35**	5.60 **5.30**	5.10 **5.35**	4.30 **4.72**	5.20 **5.84**	4.30 **4.11**	5.85 **6.55**	0.45 **0.40**
Trunk girth(cm)	40.70 **35.31**	37.70 **32.38**	37.40 **34.59**	55.80 **52.31**	56.20 **50.39**	48.10 **50.89**	55.80 **53.07**	40.10 **44.72**	59.80 **64.61**	8.06 **6.03**
Tree volume (m^3)	39.75 **24.97**	29.70 **19.33**	50.50 **48.25**	70.20 **76.57**	50.70 **48.18**	51.80 **54.23**	68.20 **75.18**	25.60 **27.25**	73.80 **110.02**	9.57 **8.95**
Shoot length (cm)	28.60 **30.33**	29.85 **28.44**	25.30 **20.55**	22.60 **19.54**	21.45 **17.11**	22.50 **11.98**	24.40 **22.54**	23.80 **25.33**	31.50 **28.88**	2.64 **2.54**
Leaf area (cm^2)	36.50 **33.46**	36.60 **34.83**	36.70 **34.45**	33.22 **31.77**	32.50 **36.44**	30.20 **36.34**	32.40 **31.61**	32.90 **35.25**	42.50 **60.76**	2.07 **0.68**
Days from bud burst to I^{st} flower open	12.50 **14.53**	9.70 **10.67**	12.10 **14.08**	9.60 **10.33**	8.30 **8.44**	10.40 **14.11**	14.50 **17.22**	10.00 **12.97**	10.60 **12.65**	1.95 **0.59**
I^{st} flower open to full bloom	10.30 **13.55**	8.30 **8.11**	9.20 **9.87**	9.20 **10.55**	8.30 **9.87**	8.10 **9.54**	10.98 **11.02**	7.10 **7.54**	7.60 **7.65**	1.86 **0.53**
No. of flowers/ unit shoot length	26.40 **23.18**	26.20 **24.76**	20.80 **16.66**	29.95 **35.34**	20.40 **19.21**	16.10 **12.79**	23.50 **20.22**	15.0 **10.95**	32.19 **36.97**	6.16 **6.43**
Fruit yield Kg/plant	28.80 **4.67**	23.50 **2.25**	33.60 **6.34**	26.70 **11.17**	22.60 **10.15**	23.50 **2.87**	25.50 **2.66**	20.80 **2.84**	38.90 **15.83**	2.56 **0.75**
Fruit weight (g)	112.80 **106.81**	85.60 **78.77**	107.20 **101.12**	120.50 **122.64**	105.70 **109.33**	66.60 **30.74**	120.30 **124.55**	106.40 **121.76**	130.20 **129.83**	7.43 **8.65**
TSS °Brix	9.40 **9.32**	11.00 **11.11**	9.90 **9.88**	10.90 **11.66**	12.10 **12.08**	12.35 **13.44**	9.50 **9.12**	10.20 **11.78**	11.20 **12.13**	0.64 **0.44**
Acidity (%)	0.23 **0.19**	0.24 **0.25**	0.44 **0.43**	0.58 **0.67**	0.37 **0.42**	0.42 **0.54**	0.39 **0.46**	0.79 **0.88**	0.38 **0.34**	0.09 **0.03**
Total sugars (%)	4.75 **4.58**	4.90 **4.81**	5.65 **5.52**	6.85 **8.33**	5.54 **5.52**	5.36 **5.75**	4.90 **4.81**	4.72 **4.84**	8.20 **8.47**	0.40 **0.21**

Cultivar Red Delicious at same location with higher chilling units requirement did not perform satisfactory as required chill units conditions were not met with. The data on chilling clearly shows that as the chill units (CU) increased from 300 to 1250 at site A the number of days taken for bud break decreased from 52 to 12 (Table 3.) and average number of buds that sprouted rose from 1.2 to 4.6 site B (Table 4.) which is a marginal site also showed variation as regards chill units accumulated and days for bud break and average number of buds sprouted (Table 5). When about 750 CU were accumulated cultivars took about 31 days for bud break and 2.4 buds sprouted on an average. The two locations showed distinct variation and clear cut indication of climate on chill unit accumulation.

Under the controlled conditions study on the effect of different chilling units on bud break, the maximum days taken for bud break of potted apple plants were under 500 chill units (CU) treatment and minimum under 1500 CU treatment. It was observed that with the increase in chill units, there was reduction in number of days required for bud break (Table 4).

Earlier, Felker and Robitaille (1985) observed that the forcing time for bud break in sour cherry decreased steadily as chilling hours increased. The number of buds sprouted after the

Table 2: Chill units based on daily maximum and minimum temperature (oC) difference for high chill congenial conditions at IARI Regional Station (Cereals and Horticultural Crops), Amartara cottage, Shimla (H.P.), INDIA.

Month	2006-07	2007-08	2008-09	2009-10	2010-11
August	0	0	0	0	0
September	0	0	0	0	0
October	32.5	1.5	13	9	6.0
November	219	124	64.5	112.5	68.5
December	464.5	449	226.5	496	369.0
January	430.5	525	403.5	459	526.0
February	446.5	431.5	325.5	438	400.0
March	299.5	28	96.5	14	169.0
April	0	0	44	0	100.0
Total chill units	1892.5	1559	1173.5	1519.5	1638.5

Table 3: Effect of chilling unit (CU) on bud break of apple (Site A).

Chilling Unit	Days for bud break	Avg. no. of buds sprouts
300	52	1.2
500	46	2.1
750	33	2.6
1000	21	3.0
1250	12	4.6
Mean±SE(M)	32.8±3.26	2.7±0.84

Table 4: Effect of chilling units (CU) on bud break of apple (Site B)

Chill units	Days for bud break	Average buds sprouted
500	49	1.3
750	31	2.4
1000	19	2.6
1250	16	3.2
1500	14	4.3
Mean + SE (M)	25.8 + 6.25	2.76 + 0.50

plants were subjected to growing conditions indicated that with the increase in chilling units there was an increase in number of sprouted buds. Young and Werner (1985) also observed similar results in apple.

Perusal of the total chill units received in Shimla during the five years of the study show that in none of the years the accumulation was less than 1000 chill units (Table 6). This is well within the range for cultivation of apples. However, the year to year fluctuations are a matter of concern and a further long term study should be continued to fully understand the impact of global warming at Shimla.

Three types of ready reckoners have been developed for estimating chilling units received at any particular location. One is in tabular format which estimates daily positive chill units (PSU) on the basis of maximum and minimum temperatures (Linsley-Noakes et al. 1995); the second is in a graph format from which total chill units perceived in a region are estimated on the basis of average temperature during the coldest month(s) (Byrne and Bacon, 1992). Both these chill unit estimation

Table 5: Accumulation of Chilling by different methods during 2006-07

Month	Hrs < 7°C	PSU	RR	DM
Oct	0.0	32.5	15.0	2.0
Nov	117.0	219.0	135.0	9.0
Dec	184.0	464.5	373.5	21.0
Jan	337.5	430.5	417.0	18.0
Feb	280.0	446.5	487.5	20.0
Mar	151.0	299.5	228.0	12.0
Sum	1069.5	1892.5	1656 .0	82.0

Nb: PSU: Positive Chill Units,DM: Dynamic Model,RR: Ready Reckoner

Table 6: Annual variations in chilling, productivity of apple and mean winter temperatures at Shimla (1980 m Above Mean Sea Level),India

Year	RR	DM	Productivity (tones/ha)*	Mean Annual Winter Temperatures (°C)
1983-84	1590	82	6.5	11.1
2006-07	1656	82	7.0	11.6
2007-08	1314	67	10.4	12.0
2008-09	1181	51	7.6	13.7
2009-10	1553	70	6.7	12.4
2010-11	1638	78	9.3	12.3

Nb: RR: Ready Reckoner, DM: Dynamic Model
* - figures obtained from the Department of Horticulture, Govt. of Himachal Pradesh, India.

models do not conform to the temperature range encountered in the apple growing regions of Shimla. Moreover though it is widely acknowledged that during the initial stages of dormancy negative chilling can accrue, yet no provision for this has been made in these two models.

The third model known as the dynamic model (Fishman et al. 1987a, b) takes cognizance of sequence of temperature variations for allotting an arbitrary unit of chilling portion. This chilling portion is hypothetical and the theory apparently holds good for subtropical regions experiencing warm winters (Fishman et al. 1987a, b; Erez et al. 1988; Perez et al. 2008; Ramirez et al. 2010). Moreover it considers reversal of chilling possible even during deep and post dormancy periods which does not explain why it becomes almost impossible to force dormant apple buds during the deep dormancy period.

Bud dormancy is a characteristic feature of temperate fruit trees that has helped them to escape cold injury to vegetative and floral organs (Peereboom Soller 1986). These crops require some critical amount of winter chilling to break the dormant stage (Saure 1985). Early dormancy is the period when it becomes increasing difficult to force the buds to grow when transferred to optimum growth temperatures – until finally it becomes impossible to force growth. This is the period (October to December under Shimla conditions) when negative chilling (Utah Model) or reversible intermediate product formation (Dynamic Model) takes place i.e. the chilling process is reversed in case high temperatures

(16°C and above) occur during this period.

The period between January and the first week of February represents the period of deep dormancy during which it is not possible to force growth of dormant apple buds. No negative chilling units can accrue or degradation of the 'intermediate product' can occur during this or later period. Hence the ready reckoner exhibits the positive chill units ignoring the negative chill units of Utah Model for this period.

This ready reckoner overcomes all the shortcomings mentioned earlier in the previously developed models for estimation of chill unit accumulation. This ready reckoner cannot be claimed to be of universal applicability since the variation between a particular maximum-minimum temperature combination is dependent on the number of daylight hours. The concept being that the more the daylight hours at a given place the longer would be the period during which relatively higher temperatures would prevail hence lesser chill units are likely to accrue and vice-versa at such locations.

A comparison was sought to be made between the traditionally counted hours below 7°C, positive chill units (PSU) of Linsley-Noakes et al. (1995) Model, the Dynamic Model (DM) and the ready reckoner (RR) developed in this study (Table 5). The lowest chill accumulation was exhibited by the traditional model. The PSU model showed the highest chill accumulation. The RR exhibits chill unit accumulation less than that by the Linsley-Noakes et al. (1995) model as it takes into account the negative chilling during the months of October to December. The other three models tend to overlook this aspect of negative chilling, while the traditional model also ignores chilling effect between temperatures 7°C and 12°C.

At the IARI Regional Station, Shimla comparative investigations have been undertaken to study the influence of winter temperatures below 7°C on effective chill units (ECU), growing degree hours Celsius (GDH0C) requirements and physiological changes associated with the bud dormancy of Starking Delicious apple under two locations viz., location A (ideal apple growing conditions with an altitude of 2286 in amsl) and location B (marginal apple growing conditions with an altitude of 1375 m amsl). Using the Utah Model, the effective chill unit requirements for location A and B were 1208 and 1130, respectively. The quantitative analysis of physiological components indicated varying pattern during the course of dormancy. The effects of various chilling units on bud break and biochemical attributes in young potted apple plants were studied under controlled conditions. It has been observed that with the increase in chilling exposure, the days required for bud break were reduced. Further, the impact of climatic conditions during winter, spring and summer are being assessed for studying the relationship with fruiting parameters of Delicious apple.

The productivity and quality apple is influenced by i) winter conditions (December to February), ii) spring conditions during flowering (April) and iii) post-bloom summer conditions (May-June). The important climatic components affecting the productivity and quality parameters are temperature, rainfall, hails and frost. The bud break to petal fall is the most sensitive stage when hail can reduce the prospective good crop year to almost `off' year. It does not only inflict direct injury to buds, flowers and leaves but can causes sublethal injury to the developing fruits and spurs as well. Hails during the fruit development have more serious effects, however, the frequent occurrence of hailstorms in Himachal Pradesh has created havoc in fruit setting in apple. It is feared heavy crop loss for the last 3-4 years may be due to hails as computed in present studies. During 2009-2010 area affected by major calamity like hailstorm was 32244 ha, 2010-2011 it was 106467 ha, 2011-12 it was 166207 ha while in the current year the affected area is 24350 hac with net loss of apple crop worth 1540 crores up to April, 2012.

MID SEASON CORRECTINS TO MITIGATE LOSS DUE TO HAIL STORM

Plastic netting

Hail netting though fool proof method has not been readily adopted by fruit growers, mainly because of high cost, and partly because of concerns relating to tree growth and fruit quality under the plastic nets. It has been shown that shading from some netting materials decrease photosynthesis especially black may interfere with the development of red colour in apple. White nets reduce radiation by 4-8 per cent and black net by 33-37 per cent. Hence, fruit colouring was less extensive under black net and little affected under white nets. The studies are in progress.

Training system

Central leader trees suffer the most total hail damage, while the modified central leader suffering the least as observed in IARI,RS, Shimla. Bagging of fruits also reduces hail damage. However, it is very laborious. The spray of urea immediately after the hail storm helps in the repairing process of hail injury. The injury caused by hail damage makes the fruits susceptible to attack of disease causing organisms. These diseases can be controlled effectively by using mild fungicides so as to reduce the loss of fruit quality on experiencing hail storm. In order to heal the damage of hail on leaves and fruits and improve the size of quality fruits two plant hormones namely CPPU (a cytokinin derivative) and 30 to 60 ppm promalin (mixture of BA and GA 4+7) at different growth stages have been tried at IARI, Regional Station, Shimla.

Use of anti hail gun

Himachal Pradesh state Department of Horticulture as a pilot project with the Dutch technology, installed three anti hail guns. Impacts on hail control are under study and standardization. Outlook-forward linkages

Climate change per se will have impact on economically important species like apple but livelihoods of farmers are being threatened treatment due to incomplete chilling, longer GDH, erratic irruptive rainfall, and snow in winter, more frequent hail storms and enhanced abiotic and biotic stresses. However, measure to adapt to these climate changes is critical for sustainable production. Increased temperature and weather vagaries will have more effect on reproductive biology. The strategies had been identified and addressed to mitigate the adverse effects of weather and development of climate resilient plants species, like low chilling crops, culture practices and efficient use of water. Concerted and integrated efforts can convert challenges into opportunity.

CONCLUSION

Meteorological data of two locations were analyzed and correlated to study the impact of changing climatic scenario on the overall temperate fruit productivity particularly apple in Himachal Pradesh. Effective chill unit accumulations (based on Utah Model were measured. The average apple productivity of the state was 6.94 t ha^{-1}, increased slightly to 7.19 t ha^{-1} and then it declined to 4.17 t ha^{-1} and again increased to 10.5 t ha^{-1}. Analysis of climatic variables under different locations indicated that there was decline in the accumulation or effective chill units (ECU) during winters from 1892 CU to 1638 CU. The relationship between productivity and chill units, i.e. coefficient of correlation (r) was positive and statistically significant. The effect of various chilling, units (500 to 1,500 CU) on bud break in young potted-apple plants was studied under controlled conditions. It was observed that with the increase in the chilling exposure, the bud break was advanced and improved.

It is clearly reflected that standard apple cultivar Starking Delicious and Red Delicious would not flower and fruit when chilling units are not adequately fulfill. Hence there is an urgent need to select appropriate low chill cultivars for plantation at low elevation location so that consistent yields are obtained and crop failures avoided. To meet the bulk requirements of the processing units and horticultural diversification, apple cultivation can be extended to mid hills by planting suitable low chilling cultivars.

It is concluded that the quantum of chill unit accumulation is location specific and cannot be accurately estimated by any generalized estimation model.

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