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Adaptation Potential of Low Chill Peach Varieties to Inter-annual Climatic Variability in the Lower Shiwalik Himalayas

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Abstract

Fruit tree production is a mid to long term investment in which only few adjustments can be done once the crop has become established. Targeting of existing varieties for expected climatic variability is therefore critical for any fruit grower. In the current studies inter-annual variability in climatic variables has been desired to be confirmed with its potential impact on variation in the phenological, production and quality traits of peach germplasm grown under the subtropical Himalayan eco-system. Different meteorological variables were monitored and behaviour of ten peach varieties were studied for their date of first bloom, full bloom fruit maturity, yield and fruit quality parameters during the years 2006-07 to 2012-13. Higher inter-annual variability in climatic variables has been confirmed together with the variation in the phenological traits. Yield and fruit quality performance of these varieties has also been evaluated. The resilience potential of varieites to climate change was ranked (in decresing order) as: Early Grande> Shan-i-Punjab> Pratap> Florida Prince> May Fire.

Highlights

- Ten low chill requiring peach varieties were evaluated
- Dispersion in phenological attributes of different peach varieties has been quantified *w.r.t* the inter-annual meteorological changes
- Significant changes in yield and fruit quality parameters have also been studied
- Adaptation score of different varieties for changing climatic conditions has been worked out
- The varieties having resilience potential for the changing climatic conditions have been identified

Keywords: *Prunus persica* (L) batch, climate change, resilience, phenology, prioritization

Introduction

Climate change is here, and it is here to stay; predictions point to a warmer world with an estimated increase in temperature 1.5 to 2.5^{0}C by 2050 (Darr, 2011). Climate change mediated global warming is expected to bring big changes in Indian agriculture in the years to come. It has been estimated that a small change of 2^{0}C summer temperature or 0.5^{0}C change in winter temperature will

decrease rice and wheat yield by 0.75 t/ha and 0.45 t/ha, respectively (Singh, 2012). Little is known in detail about the vulnerability of mountain ecosystems to climate change. Lower Shivalik hills are chiefly composed of sand stone and conglomerate with alluvial depositions in the lower basin areas, therefore slight variation in the meteorological parameters like rainfall distribution or temperature brings drastic changes in the crop productivity of the region. Geographically this region has been characterized as subtropical (Thornwaite, 1948) but due prevalence of intense winter and frost, the region is sub-optimal for subtropical fruit growing. Therefore, horticultural growth in the region is highly challenged and need systematic evaluation of plant resources for sustained development under changing climatic scenario.

As per the experts, the detrimental effects of climate change can be mitigated by adoption of crop plant germplasm which has greater capacity to with stand and buffer the impact of changing climatic conditions. We have a wide pool of wild plant genetic resources which possess the potential to withstand the steady changes of weather parameters. But, these resources are yet to be tested on commercial scale and it is quite probable that much of this material may not come to the expectation of growing world fruit market.

Among the cultivated fruit species, if we scan history peach has shown wide adaptation. It was first domesticated in China about 4000 years ago from where it moved to Persia (Iran) from where it made its way across the Globe. When considering a broad cross section of climates and growing regions, peach is the most prevalent of the stone fruits, rivaling apple in terms of adaptation. Genesis of its germplasm with varied chilling requirement drove its rapid dissemination and selection for adaptation to new areas. Today more Mendelian transmitted traits are understood in peach than in any other tree (Scorza and Sherman, 1996). These facets, in conjunction with a small genome size have made peach a desirable crop for breeders having the goal of tree fruit improvement.

It is well established that peach tree requires a period of winter dormancy or chilling to resume normal spring growth. The required amount of chilling varies widely among the peach cultivars (Weinberger, 1967). Inadequate chilling and spring frost are considered to be two most potential hazards for peach growing in the subtropical areas. Most of the low chilling varieties of peach require about 250 to 500 chilling hours and do not with stand temperature below -2.2^{O}C after bud burst (Kish and Purceis, 1975 and Carbone and Schwartz, 1993). In the low hill region of Himachal Pradesh average chill hour accumulation is about 650 hours (Sharma and Badiyala, 2008) and with the expected increase of 1^{O}C in the atmospheric temperature in the years to come the winter chill hour accumulation is probable to fall to the level of about 496 hours (the calculation for fall in chill hours with increase in temperature is based on Carbone and Schwartz, 1993). As far as spring frost is concerned, the current trend indicates that spring temperature in the region will rarely fall below -0.2 ^{O}C. Keeping in view the above stated facts, the present studies were designed to examine the behaviour of different peach varieties to inter-annual climatic variations in the lower Shiwalik Himalayas and to evaluated the their capacity to buffer the expected climatic changes in the years to come.

Materials and Methods

The studies were conducted at the experimental orchards (31^{0} 41'N and 76^{0} 28'E) of the Institute of Biotechnology and Environmental Science Neri, during the years 2006 to 2013. Early Grande (v_1), Florida Prince (v_2), Florida Sun (v_3), July Elberta (v_4), May Fire (v_5), Prabhat (v_6), Pratap (v_7), Red Heaven (v_8), Shan-i-Punjab (v_9) and Snow Queen (v_{10}) were the varieties selected for the studies. For each variety, ten uniformly growing trees comprised unit of observation and the performance of individual variety was evaluated on the basis of fruit set, cumulative yield and fruit quality parameters. Fruit set was expressed as percent of flowers that grew into fruit lets (randomly five shoots of one meter length were selected per experimental tree for comprising a unit of observation). Cumulative yield was measured as the sum total of the harvestable yield (kg) from individual experimental tree. Fruit quality was accessed in terms of fruit weight (g), total soluble solid (^{0}B), it was measured with Erma Hand refrectrometer (0-32°B)) and titerable acidity (estimated as per standard procedure described by AOAC, 1980). Fruit firmness was evaluated by a panel of expert over an arbitrary scale of 1-10 points, where 10 is considered as the most desirable state of firmness. The yearly data were pooled and analyzed as per standard statistical procedures.

Meteorological parameters like minimum temperature, maximum temperature, average temperature, minimum relative humidity, maximum relative humidity, average relative humidity were recorded with Maditech automatic data loggers. The data for rainfall were obtained from local agricultural department database. The variables which exhibited significant inter-annual variability have only been

presented over here. Winter accumulation of chilling hours was computed on the basis of maximum and minimum temperature as per procedure described by by Aron and Gat (1991) and Byrne and Bacon (1992). As accumulation of chilling hours unto December was small, it was computed unto December collectively and after that it was grouped as weekly averages (except for the last week of January or February for the leap year where the last week observations comprised unto last day of the month). The year to year deviation in the meteorological observations was measured as Standard Deviation (SD). The level of significance of SD was tested with standard F-test at P=0.05. In order to quantify inter-annual variation in numerical terms the confidence limit of the individual variable was composed as per procedure described by Gupta and Gupta (1995). It has been expressed as a $\pm$ value to be added or subtracted to the mean value to get confidence limit of the variable at $P < 0.05$.

Phenological patterns are most diverse and least understood in the sub-Himalayan Subtropics. Changes in plant phenology are one of the earliest responses to inter annual climatic variations. The phenological responses of different peach varieties were studied manually and the observations were taken on date of first bloom, date of full bloom and date of fruit harvest maturity. Date of first bloom was taken as the calendar date on which first flower bloomed on experimental trees. Date of full bloom was taken as the date on which more than 70% of the flowers were at full bloom. Fruit maturity was adjudged by the development of red fruit colour and the shoulder fullness of the fruits. The standard deviation and confidence limits of the variables were calculated as described above for the meteorological parameters. In order to be more precise on pattern of dispersion of the variables around the mean and to have idea about the frequent and infrequent extreme deviations, the kurtosis of the variables was computed as per procedure described by Gupta and Gupta (1995).

On the basis of dispersion data of different traits studied, the adaptation potential of the different peach cultivars to the inter-annual variations was assessed as per method described by Kunen (1992) and Gosenheimer (2012). Apart from the phenological parameters yield and fruit quality parameters have major contribution for judging the economical potential of the peach varieties, therefore these parameters were also included for making final judgment on the adaptation potential of the peach varieties under changing climatic scenario. For this work individual trait (Date of first bloom-A_1, full bloom-A_2, maturity-A_3, yield-A_4, fruit weight-A_5, TSS-A_6, Acidity-A_7 and Firmness-A8) was treated as a separate 'Set' -A_i. Top five varieties (v_1 and/or v_2, and/or v_3… and/or v_{10}) shortlisted in respect of each trait selected were treated as the elements (v_i) of the set. Each set was then assigned a weight by three experts and the average value obtained was designated as relative weight (w) of t he set. Score was the figure derived from the product of the element and the respective weight of the set. Cumulative adaptation score for each element/ variety was derived as the sum total of the score of each element obtained under different sets. The variety which was having highest cumulative score has been considered to have the best adaptation potential under the changing climatic scenario.

Results and Discussion

Yield and fruit quality of different peach varieties: The pooled data on cummulative yield and fruit quality of the different peach cultivars under study has been presented in Table 1. It is evident that there occurred no significant difference in the Fruit set of different cultivars except that for Snow Queen, Red Heaven and July Elberta which were having comparatively lower fruit set. Fruit weight was recorded highest for the cultivars Pratap (69g) and statistically it was at par with Shan-i-Punjab, Early

a) Grande, Florida Prince and July Elberta. Fruit weight of May Fire, Snow Queen and Florida Sun was found to be in the middle order (52-57g) whereas average fruit weight of Prabhat and Red Heaven was recorded lowest (42 and 40 g). The highest cummulative yield for the period of study was recorded for Shan-i- Punjab (91 kg) but it was not higher than that of cultivar Early Grande, statistically. Yield of cultivars Florda Sun Florida Prince, Pratap and Prabhat was also statistically at par with each other (50-67 kg), whereas the cumulative yield of the cultivars Red Heaven, Snow Queen and July Elberta was found to be considerably lower in comparison to other varieties. Total soluble solids (TSS) content of the fruit juice was recorded highest for the cultivar May Fire (13.8^0B) though it was at par with Early Grande (13.4^0B), Shan-i-Punjab, Prabhat and Pratap. Acid content was recorded lowest for cultivar Prabhat (0.51%) and it was at par with the acidity of cultivar May Fire, Snow Queen, Pratap, Early Grande and July Elberta. Fruit firmness was found to be most desireable for the cultivar Early Grande and Shan-i- Punjab and it was statistically similar to that of cultivars May Fire Pratap and Snow Queen. Poorest fruit firmness was recorded for the cultivar Prabhat.

Table 1: Fruit set, yield and fruit quality of different peach varieties

Variety	Fruit Set (%)	Fruit Weight (g)	Cummulative yield (Kg/tree)	TSS (°B)	Acidity (%)	Firmness*
Shan-i- Pb	64.3	64	91	12.8	1.65	10
Florda Sun	67.6	52	62	12.2	1.20	7
Early Grande	69.4	60	78	13.4	1.07	10
May Fire	62.3	57	54	13.8	0.98	9
Prabhat	65.3	42	50	12.9	0.51	6
Pratap	62	69	67	12.5	1.01	9
Florida Prince	67.3	58	65	12.0	1.35	7
Snow Queen	33.4	57	34	12.2	0.98	8
Red Heaven	44.3	40	31	12.2	1.92	7
July Elberta	43.4	58	31	11.1	1.05	7
$CD_{(0.05)}$	15.8	12.3	18.4	1.12	0.62	2.62

(Pooled average for the years 2006-07 to 2012-13)

** Rated on 1 to 10 scale, 10 is most desirable firmness*

Performance of peach cultivars under subtropical conditions were also evaluated by Dozier *et al*. (1998) and Kanwar (2002) and the results presented above are in close conformity with their findings.

b) Inter-annual variation in meteorological parameters: Out of the variables; minimum temperature, maximum temperature, average temperature, minimum relative humidity, maximum relative humidity, average relative humidity; significant inter-annual variations were observed only for- maximum temperature, rainfall and average relative humidity.

Maximum Temperature: Standard Deviation of the data represented through Fig. 1 illustrates that inter-annual variation in maximum temperature was significant and this variation was smaller during early winters. The confidence limit of the variables indicated that there occurred a deviation of $\pm 1.4^0$C in the mean maximum temperature during the first week of January. Highest inter-annual variation in maximum temperature was observed during 3rd week of January where confidence value for mean maximum temperature was observed to be ± 2.7 ^{0}C.

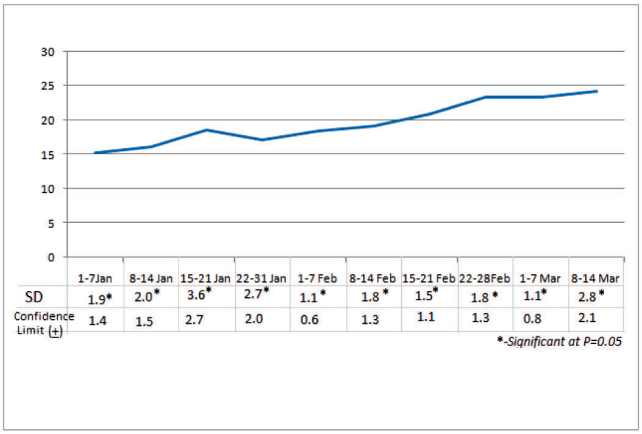


Fig. 1: Variation in maximum temperature at different time intervals during winter (Pooled averages for the years 2006-07 to 2012-13)

During winters the daily maximum temperature has a great role to play; it largely governs the return bloom in dormant species provided the chilling and moisture conditions are full filled. Therefore, it is inferred that variation maximum temperature might have influenced the flowering in different varieties. If variation is toward higher side of temperature it might have favoured flowering whereas, the years during which there was drop in maximum temperature prior to flowering, it might have delayed flowering. Temperature regulated flowering has been reported by a number of workers in case of temperate fruits (Chemielewski and Rotzer, 2001; Elzinga *et al*.,2007and Weinberger 1950). Tooke and Battey (2010) described strong correlation between warmer temperature and earliness of spring.

Rainfall: There was observed high variability in the rainfall data (Fig 2) across the years at different intervals during winters. High and significant variation in standard deviation for inter-annual rainfall indicated no systematic trend of rains at different time intervals during the winters. Confidence limits at P=0.05 indicated that there occurred deviation of $\pm$ 11 to $\pm$39mm at different time intervals during winters. The highest deviation was observed during 22-28 February followed by 8-14 February and 8-14 January which has been the bloom period for most of the peach varieties. Winter rains are strong player in continuation

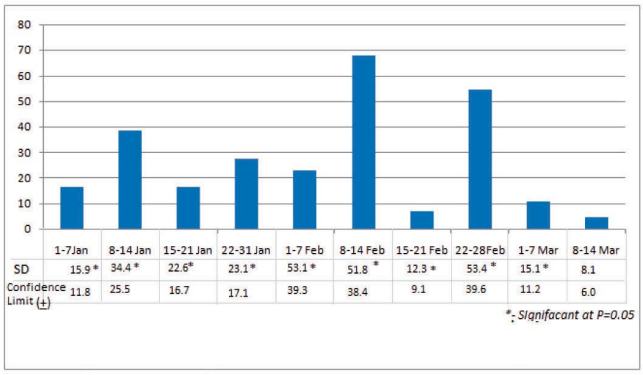


Fig. 2: Rainfall (mm) received at different time intervals during winters (Pooled average for the years (2006-07 to 2012-13)

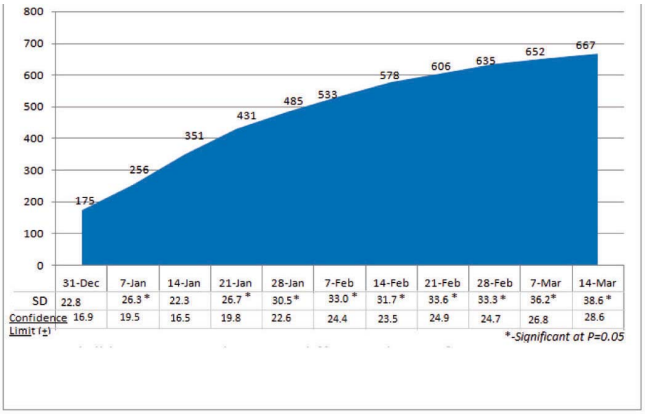


Fig. 3: Chill hour accumulation at different dates of winter season (Pooled average for the years 2006-07 to 2012-13)

of dormancy as well as release of dormancy especially in tree species. In many peach varieties it has been observed that after completion of chilling requirement full bloom get delayed (even if first bloom has occurred) if there is moisture stress, and if such plants are watered adequately they observe full bloom within next 3 to 4 days. Faust *et al.* (1997) and De-Fay *et al.* (2000) have demonstrated the movement of water to buds and its role in return bloom in woody perennials. Post dormancy water deficit thus has been found to influence the phenological sequences of the peach tree.

Chill Hours: The pooled data on accumulation of chill hours at different time intervals during winters of the year 2006-07 to 2012-13 are presented in Fig. 3. Unto end of December there was average accumulation of 175 chill hours. Further increment of 81, 95, 80 and 54 chill hours was observed on an average unto 7th, 14th, 21st and 31st January, respectively. By the end of January there was accumulation of about 485 hours and it varied by ±23 hours during the different years of observation. By the end of February there was observed total accumulation of about 635 hours. Very small increase in chill hours was observed during March. Significant standard deviation was observed for inter-annual variation in chill hour accumulation over different time intervals. Weekly chill unit accumulation varied by ±16.5 to ±22.6 hours(Confidence limit, Fig. 3).

Year to year variation in chill hour accumulation actually influence the phenological behaviour of the fruit plants. As cited by Westwood (1978) the actual performance of most of the temperate fruit germplasm cannot be judged correctly under inconsistent climatic conditions as it affects the biological rhythms of the plant. Insufficient chilling for example may lead to delayed flowering and foliation, buttoning and reduced fruit quality (Byrne and Bacon, 1992).

c) Inter-annual variation in Phenological attributes

First Bloom: Flowering pattern of different peach varieties was studied for the years 2006-07 to 2012-13 and the pooled observations for these years are presented in Illustration 1. Earliest to bloom cultivars was found to be Prabhat (27th January) followed by Florida Prince, Early Grande and Florida Sun. The cultivars, Pratap, Shan-i-Punjab and May Fire were found to be in the middle segment (5-8 February) whereas Red Heaven, Snow Queen and July Elberta were comparatively late (15-24 February) in producing first bloom. From Fig. 3 and Illustration 1 it may be inferred that for completion of rest/dormancy in early mid and late segment varieties about 485, 533 and 570 hours of chilling were needed with a deviation range of ±31 hours. As far as inter-annual variation in date of first bloom was concerned minimum standard deviation was observed for Early Grande followed by Prabhat, Florida Prince and Shan-i-Punjab. For these varieties date of first bloom deviated from mean by ± 2.31, 3.56, 3.90 and 4.89 days (confidence limit) during the years of studies. Kurtosis value further indicated that dispersion was higher for Prabhat than the other three varieties described above, there was very less abrupt change observed in first bloom of Early Grande (Kurtosis = -0.8) followed by Florida Prince and Shan-i-Punjab. It implies that date of first bloom was more consistent in Early Grande. Comparatively larger kurtosis value in case of Prabhat and other varieties may be attributed to the larger variation in maximum temperature during 2nd and 3rd week of January (Fig. 1) which might have influenced the consistency of these cultivars. Temperature

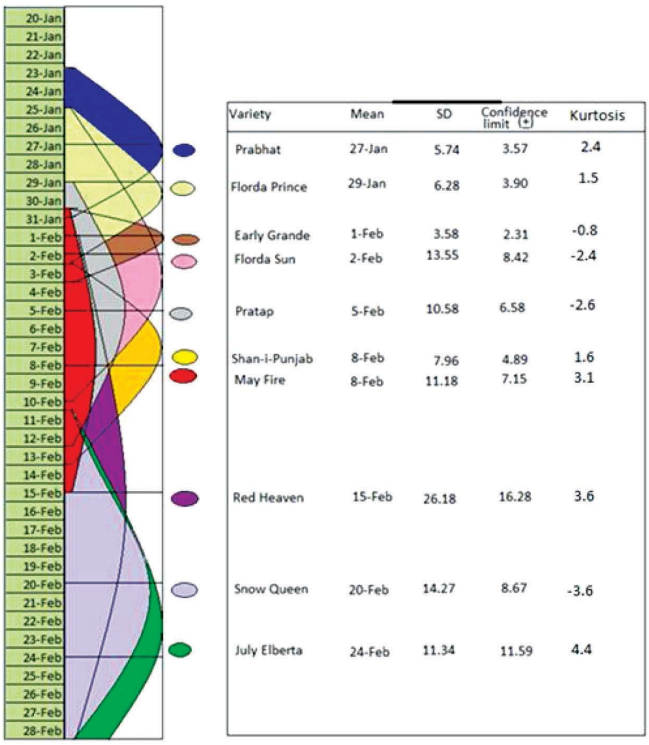


Illustration 1: Date of first bloom of different peach varieties (Pooled average for the years 2006-07 to 2012-13)

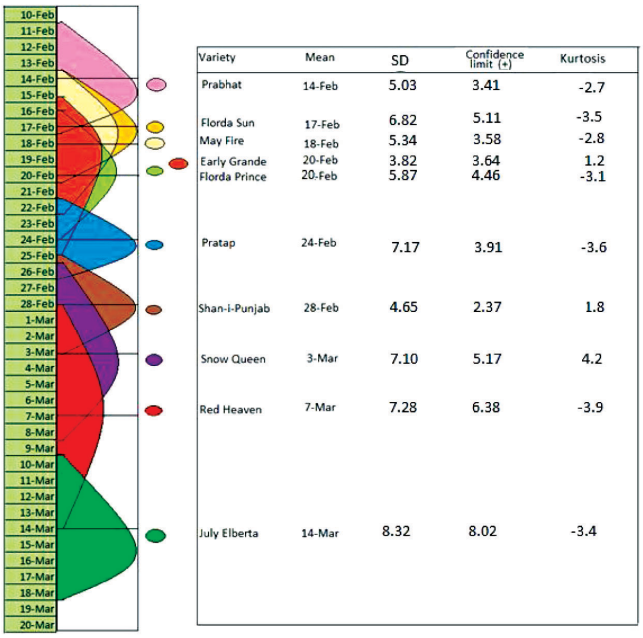
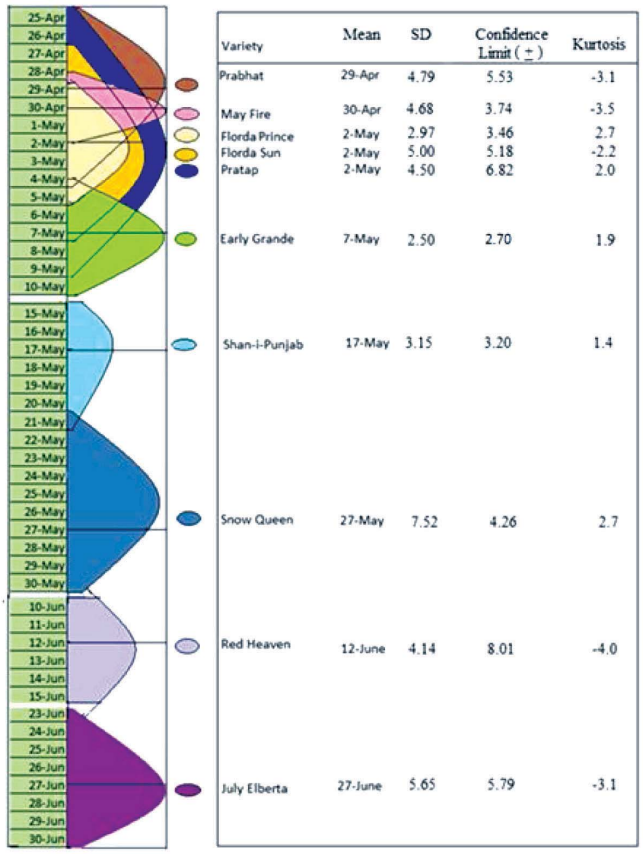


Illustration 2: Date of first bloom of different peach varieties (Pooled average for the years 2006-07 to 2012-13)

and rainfall related phenological and morphological changes have also been reported in mango by Navjot *et al*., (2012) who mentioned clearly about earliness or delay in flowering with shift in temperature pattern and rainfall.

Full Bloom: Earliest to bloom cultivars was found to be Prabhat (14th February) followed by Florida Sun, May Fire, Early Grande and Florida Prince (Illustration 2). Pratap and Shan-i-Punjab were in the middle segment as far as full bloom was concerned. Snow Queen, Red Heaven, and July Elberta were comparatively late in attaining full bloom. The inter-annual deviation from mean value of date of full bloom was lowest for variety Early Grande followed by Shan-i-Punjab, Prabhat and May Fire. Confidence limit indicated that flowering of these varieties deviated by ± 3.64, 2.37, 3.41 and 3.08 days respectively. Kurtosis values indicated that among these cultivars deviation was less abrupt in Early Grande (Kurtosis=1.2), Shan-i-Punjab, May Fire and Florida Prince. Consistency in date of full bloom of other varieties was comparatively lesser. The cause of inconsistency in date of full bloom may be attributed to their inability to withstand variation in the meteorological parameters (Figure 1 to 3) to which the above said varieties might have been more tolerant.

Fruit Maturity: The trend of fruit maturity was also all most similar to that observed for flowering. Prabhat has been found to be the earliest maturing cultivar followed by May Fire, Florida Prince, Florida Sun and Pratap (Illustration 3). These varieties attained harvestable maturity between 29th April and 2nd May. Early Grande Matured by 7th May whereas by Shan-i-Punjab matured on 17th May. Snow Queen, Red Heaven and July Elberta were comparatively late in fruit maturity. As far as the inter-annual climatic variation on date of fruit maturity was concerned, the minimum standard deviation was observed for Early Grande followed by Shan-i-Punjab, May Fire and Pratap and Prabhat. The deviation in date of fruit maturity of these cultivars was observed to be between ± 2.70 to 5.53 days from their respective mean value. Kurtosis value further indicated that varieties May Fire and Prabhat were having more platykurtotic distribution which implies that most values of the observation lied above mean and there existed some values which were quite far from the mean. On the other hand lowest kurtosis value was observed for variety Shan-i-Punjab followed by Early Grande, Florida Prince and May Fire indicating greater consistency of these cultivars toward the mean date of fruit maturity.



Variety	Mean	SD	Confidence Limit (±)	Kurtosis
Prabhat	29-Apr	4.79	5.53	-3.1
May Fire	30-Apr	4.68	3.74	-3.5
Florda Prince	2-May	2.97	3.46	2.7
Florda Sun	2-May	5.00	5.18	-2.2
Pratap	2-May	4.50	6.82	2.0
Early Grande	7-May	2.50	2.70	1.9
Shan-i-Punjab	17-May	3.15	3.20	1.4
Snow Queen	27-May	7.52	4.26	2.7
Red Heaven	12-June	4.14	8.01	-4.0
July Elberta	27-June	5.65	5.79	-3.1

Illustration 3: Fruit Maturity of Different Peach Cultivars (Pooled Average for the Years 2007 to 2013)

Being non climacteric fruit, maturity of peach fruit is of great significance as once it is harvested from tree, the fruit quality parameters do not improve further. Therefore influence of inter-annual variation on maturity time actually hampers the authenticity of the most accepted maturity index that is the one based on number of days from date of full bloom. The harvest maturity index thus holds good only if there is consistency in the flowering date as well as the fruit maturity date which are otherwise happens to be highly variable under the changing climatic scenario. These findings are thus in close proximity with Rosenzweig (1990) and Tombesi *et al.*, (2010).

d) Assessment of adaptation potential: The detailed analysis on the adaptation potential of different peach varieties is presented in Table 2. It is evident from the data presented that the cultivars Early Grande (v_1) was found to be the element of almost every set followed by Shan-i-Punjab (v_9) which was found to be member of seven sets out of the eight sets observed. On the basis of weighted score the cumulative score derived resulted in relative order of adaptation potential of the cultivars as: Early Grande>Shan-i-Punjab>Pratap>Florida Prince>May Fire. As far as the climate resilience of the peach varieties is concerned there is hardy any information available especially for the subtropical conditions. Higher adaptability of the cultivar Early Grande has also been reported by Ahmed *et al.*, (2002) from Islamabad region of Pakistan. Whereas, Kanwar *et.al.*, (2002) reprted Early Grande as second best performer after Florida Prince grown under Indian Punjab. The performance of the other varieties as observed under the present studies is in close conformity of the above said authors.

Table 2: Cumulative adaptation score of different peach varieties in respect of changing climatic conditions

Set (A)	Elements (v)	Relative Weight of (A)	Score
A_1	$\{v_1, v_2, v_6, v_7, v_9\}$	3	$3x\{v_1, v_2, v_6, v_7, v_9\}$
A_2	$\{v_1, v_2, v_5, v_6, v_9\}$	4	$4x\{v_1, v_2, v_5, v_6, v_9\}$
A_3	$\{v_{10}, v_5, v_7, v_9\}$	5	$5x\{v_1, v_3, v_5, v_7, v_9\}$
A_4	$\{v_1, v_2, v_3, v_7, v_9\}$	5	$5x\{v_1, v_2, v_3, v_7, v_9\}$
A_5	$\{v_1, v_2, v_5, v_9, v_{10}\}$	3	$3x\{v_1, v_2, v_5, v_9, v_{10}\}$
A_6	$\{v_1, v_2, v_6, v_7, v_{10}\}$	2	$2x\{v_1, v_2, v_6, v_7, v_{10}\}$
A_7	$\{v_1, v_5, v_6, v_7, v_9\}$	1	$1x\{v_1, v_5, v_6, v_7, v_9\}$
A_8	$\{v_1, v_5, v_7, v_9, v_{10}\}$	2	$2x\{v_1, v_5, v_7, v_9, v_{10}\}$
Cummulative Adaptation Score		v_1= 25, v_2=17, v_3=5, v_5=15, v_6= 10, v_7=20, v_9=23, v_{10}=7	

Conclusion

Selection of germplasm with consistence flowering and fruiting behaviour under changing climatic scenario is the prime area of reseach these days. From the results discussed above it can be concluded that climatic change practically exists and it has consepicuous implications on phenotypic and production variables. The Varities like Early Grande, Shan-i-Punjab and Pratap has shown consistency in their performance *w.r.t.* the inter-annual variations observed from 2006-07 to 2012-13. Therefore, it can be concluded that these varieties may be given impetus for having sustained development of horticulture in the subtropical Shiwalik Hills of the country.

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