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***Short Communication***

# Trend of chilling hours over north-west India

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Climate change is likely to affect chilling requirements of the temperate fruits (Baldocchi and Wong, 2008). Reduction in snowfall, change in temperatures, abrupt rainfall patterns, hailstorms, droughts, torrential rains, floods, cloud busts and decreasing trend in chilling hours can be ascribed to the decreased apple productivity (Gautam *et al.,* 2014; Dutt, 2014). The apple belt in Himachal Pradesh is shifting towards higher altitudes (Rana *et al.,* 2011) in want of chilling requirement and apple cultivation is expanding in the cold desert in recent decades (Singh and Patel, 2017).The amount of cold needed by a plant during dormant period to resume normal spring growth following the winter period is commonly referred to as its chilling requirement which is specific to the crop and cultivars. If chilling requirement is not met then the buds develop one or more physiological disorders like delayed foliation, reduced fruit set and increased buttoning and hence reduced fruit quality and yield. A number of efforts have been made to model this agroclimatic factor. Many chilling models are characterized by differential weighting of temperature ranges like Utah Model (Richardson *et al.,*1974), North Carolina Model (Shaltout and Unrath, 1983), Modified Utah Model (Linvill, 1990), regional models in Georgia and Florida (Chmielewski *et al.,*2011). All models developed for chilling hour's computation requires hourly temperature data which are rarely available.

In the present study an attempt has been made to work out the trends in chilling hours using 35 years of meteorological data of 22 stations of north-west India comprising of Jammu & Kashmir, Himachal Pradesh, Uttarakhand, Punjab, Haryana, Chandigarh, Delhi, western Uttar Pradesh and north parts of Rajasthan. The altitude of area varies between 200 to 8600 meters above mean sea level. It has geographic features like the cold desert, the higher Himalaya, the middle Himalaya, the lower Himalaya, the Shivalik hills, semi desert sandy plains, the Aravali range and the hot Thar Desert (Table 1). Based on the altitude, the study area was divided into hills (>1000 meters) and plains (<1000 m).

Daily maximum and minimum temperature data of twenty two locations were collected from India Meteorological Department), Central Research Institutes for Dry Land Agriculture (CRIDA), revenue departments,State Agricultural Universities (SAUs), Regional Research Stations (RRS), Regional Horticultural Research Stations etc.Annual and monthly mean of maximum, minimum and mean temperatures were calculated. Statistical measures like standard deviation, coefficient of variation, slope, standard error, t-values, significance (probability) and regression coefficient were computed using 'OP Stat" software from daily temperature data of more than 30 years at each station. Annual, seasonal and decadal statistical measures were computed for hills, plains and for north-west India as a whole.

***Computation of chilling hours (CH)***

In the present study the Linvill (1990) model was used who proposed a method for simulating hourly observations for day and night from daily maximum and minimum temperature. The temperature wave from sunrise to sunset can be described as:

$$T(t) = T_{max}-T_{min}) \times \sin [(\pi \times t)/DL+4)]$$

Where, $T(t)$ = Temperature at time t after sun-rise

$T_{max}$ = Maximum temperature

$T_{min}$ = Minimum temperature

DL = Day length (h).

Assuming that minimum temperature occurs at sunrise, the night time cooling temperature wave from sunset to sunrise can be described as:

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**Table1:** Statistical measures for annual chilling hours at different stations of N-W India

| Regions | Station | Latitude | Longitude | Altitude | CH Group | CH | CV(%) | Slope | 't' | 'p' | $R^2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Hills | Srinagar | 34.09 | 74.79 | 1600 | >1400 | 2436.6 | 15.8 | -25.50 | -3.80 | 0.000 | 0.341 |
| | Ranichauri | 32.27 | 77.17 | 2050 | | 1480.5 | 17.6 | -1.44 | -0.26 | 0.791 | 0.002 |
| | Manali | 31.11 | 77.17 | 2397 | 1000-1400 | 1185.2 | 28.1 | -17.19 | -3.58 | 0.001 | 0.280 |
| | Shimla | 32.12 | 76.53 | 1219 | | 1097.2 | 27.4 | -16.57 | -3.51 | 0.001 | 0.284 |
| | Palampur | 30.92 | 77.12 | 1600 | 400-1000 | 521.4 | 26.4 | -9.20 | -1.53 | 0.123 | 0.127 |
| | Solan | 30.06 | 78.99 | 1950 | | 458.3 | 6.0 | -2.55 | -4.85 | 0.000 | 0.495 |
| Plains | Saharanpur | 29.96 | 77.54 | 268 | | 408.8 | 13.4 | -10.59 | -2.05 | 0.045 | 0.344 |
| | Bawal | 28.08 | 76.58 | 266 | 200-400 | 391.9 | 24.3 | -2.43 | -1.35 | 0.186 | 0.058 |
| | Hisar | 29.15 | 75.71 | 215 | | 349.6 | 25.6 | -1.56 | -1.54 | 0.130 | 0.053 |
| | Narnaul | 28.01 | 76.01 | 308 | | 280.8 | 28.0 | 1.53 | 1.33 | 0.181 | 0.047 |
| | Bathinda | 30.23 | 74.95 | 201 | | 280.3 | 30.4 | -4.15 | -2.52 | 0.014 | 0.184 |
| | Ludhiana | 30.91 | 75.85 | 244 | | 272.6 | 29.9 | -2.02 | -1.12 | 0.271 | 0.045 |
| | Sirsa | 29.53 | 75.01 | 205 | | 230.0 | 29.4 | -3.33 | -2.54 | 0.013 | 0.187 |
| | Karnal | 29.69 | 76.98 | 245 | <200 | 192.1 | 37.2 | 0.22 | 0.25 | 0.802 | 0.002 |
| | Ganganagar | 29.92 | 73.88 | 178 | | 184.5 | 26.4 | -0.42 | -0.46 | 0.648 | 0.007 |
| | Jammu | 32.73 | 74.87 | 327 | | 180.0 | 51.9 | 4.49 | 2.19 | 0.037 | 0.156 |
| | Delhi | 28.62 | 77.21 | 216 | | 174.7 | 34.3 | 1.33 | 1.11 | 0.275 | 0.041 |
| | Patiala | 30.34 | 76.38 | 350 | | 166.6 | 30.9 | -0.95 | -0.91 | 0.369 | 0.028 |
| | Ambala | 30.38 | 76.78 | 264 | | 151.9 | 47.4 | 0.24 | 0.21 | 0.832 | 0.001 |
| | Rohtak | 28.89 | 76.57 | 220 | | 144.6 | 43.8 | 2.78 | -2.02 | 0.050 | 0.095 |
| | Chandigarh | 30.75 | 76.78 | 321 | | 121.8 | 53.5 | 2.36 | 2.09 | 0.045 | 0.123 |
| | Jaipur | 26.91 | 75.81 | 431 | | 29.9 | 104.4 | 0.37 | 0.70 | 0.490 | 0.015 |
| NW | Hills | - | - | - | | 5878 | 20.2 | -8.38 | -2.92 | 0.153 | 0.274 |
| India | Plains | - | - | - | | 4860 | 38.2 | -0.09 | -0.41 | 0.274 | 0.000 |
| | NW India | - | - | - | | 10739 | 33.3 | -2.22 | -1.10 | 0.241 | 0.172 |

p=probability of error; 't' = 2.750 at 1% and 2.042 at 5%

$$T(t) = Ts - [(T_s - T_{min})/(24\ \ln\text{-DL})] \times \ln(t)$$

Where, T(t) = Temperature at time t > 1 hr after sunset

$T_s$ = The sunset temperature obtained from day time temperature wave.

The chilling hour model is simple and widely used, chilling hours are calculated using this model in this study.

Chilling hours = $\Sigma$ -2° C < CH < 7° C
Where,

CH is a chilling hour.

***Descriptive statistics of chilling hours***

Chilling hour accumulation started in the month of October and continued up to April at Srinagar, for five months from November to March at Ranichauri, Manali, Shimla, Solan and from November to February at Palampur (Table 1). In the plains Bathinda, Hisar, Sirsa experienced chilling hours from November to February) and remaining twelve stations from December to February. The annual available normal chilling hours varied from 1400 to 2500 at Shimla, Manali, Ranichauri and Srinagar, from 300-600 hours at Hisar, Bawal, Saharanpur, Solan and Palampur and less than three hundred at remaining thirteen stations. The maximum numbers of chilling hours were available at Srinagar (2436.6) and minimum at Jaipur (29.9). The coefficient of variation was highest for Jaipur (104.4%) and lowest for Solan (6.0%). The normal chilling hours for hills, plains and north-west India were 1196.5 ± 240.6, 222.5 ± 69.3 and 488.2 ± 166 with coefficient of variation of 20.2, 38.2 and 33.3 per cent (Table 1).The slope value was negative for all the three areas (hills, plain and north-west India) with highest decreasing rate of (-8.38 Ch/year)in hills (Table1).The t-value was -2.92, -0.41 and -1.1 and significance of $R^2$ was 0.15, 0.27 and 0.24 for hills, plains and north-west India, respectively.A decreasing trend in chilling hour was observed at Manali, Shimla, Palampur, Solan and Ranichauri. This may be the reason for the shifting of temperate fruit belt towards higher and higher altitudes (Rana *et al.,* 2011) and apple cultivation expanded in the cold desert in recent decades (Singh and Patel, 2017).Similar trend was observed by Jangra and Singh (2011) and Singh and Bhatia (2011) for mid hill region of Himachal Pradesh.

The availability of chilling hours in a particular area is the deciding parameter for selection of crop and varieties for that area. Based on availability in chilling hours, the north-west India was divided into five zones for fruit production in NW India (<200, 200-400, 400-1000, 1000-1400 and >1400 CH). The distribution of normal availability of chilling hours in north-west India ranged from 29.9in south-west (Jaipur) to 2436.6 in north-east (Srinagar) and showed an increasing trend from south-west to north-east of area under study. This was probably due to freezing/negative temperatures were available for longer period in hills as compared to plains.

Thus, it can be concluded that the chilling hours showed a decreasing trend at Srinagar, Manali, Shimla, Palampur, Solan, Ranichauri, Saharanpur, Patiala, Ludhiana, Rohtak, Bathinda, Hisar, Sirsa, Bawal and Ganganagar stations and increasing trend at remaining stations.The study may be beneficial for the selection of crop and varieties especially for temperate fruits for a particular area and location. It can be further refined by taking more and more station in consideration.

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