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PHENO-THERMAL RESPONSE OF PEARS IN WESTERN INDO GANGETIC PLAIN

1. The pear tree remains in dormancy during December and January and bud break takes place from first week of February after completing the chilling requirements. Prevailing weather conditions during the whole crop growing season have direct bearing upon the phenological events of the crop which ultimately affect the crop yield. The duration of each growth phase is a result of crop response to external environmental factors. Temperature is one of the important elements of the climate which determines directly the potential productivity level particularly for winter crops and temperate fruits. Thermal time effect has been described as the independent variable to delineate plant growth and development (Dwyer and Stewart, 1986). Temperature based agrometeorological indices like GDD, HTU, PTU and HYTU are based on the concept that real time to attain the phenological stages is linearly related to temperature in the range between base temperature and the optimum temperature (Monteith, 1981). This concept is widely used for assessing growth, phenological development and yield of different crops (Rajput *et al.*, 1987; Shanker *et al.*, 1996; Swan *et al.*, 1989). Such work has been done in many winter crops elsewhere (Rao *et al.*, 1999) but has not hitherto been reported from semi arid region of Haryana especially on fruit crops.

Pear (*Pyrus* spp.) is one of the important fruits of the temperate region of the world native to Eastern Europe and South Western Asia. Among temperate fruits, it ranks second, only next to apple in many respects *viz.*, global importance, diversity of existence, acreage and production. Selection and development of low chill pear cultivars had made its cultivation possible in the *tarai*, trans gangetic plain of subtropical regions also. Patharnakh (a hard variety of pear) is being cultivated on more than 85 per cent of the area under pear, followed by soft pear cultivars like Le Conte, Bagugosha and Punjab Beauty. But one of the major limitations of pear production is the spring frost, which may kill the blossoms completely and will make the orchard unproductive. Hence, the present investigation was carried out to assess the response of phenology and fruit yield of pear cultivars (Patharnakh and Punjab Beauty) to the growing degree days and heat unit utilization under semi arid conditions of Indo Gangetic Plain.

Patharnakh (PN): Patharnakh (*Pyrus pyrifolia*, Burm. F. Nakai) originated in China from where Chinese merchants and settlers brought it to Amritsar's village

Harsa Chhina during the time of Lord Kanishka. From here Patharnakh spread to other areas. It is very important cultivar of hard pear group and requires only 250-300 chilling hours for flowering and fruiting. It is a heavy bearer with well sized, firm fruits with average yield of 1.5 quintals per tree.

Punjab Beauty (PB): The trees are upright in growth; forms pyramid shape, with medium vigor and area regular bearer. It resembles 'Le conte' cultivar in tree shape and foliage. Fruits are medium in size, yellow in colours with red blush at full maturity. Fruits mature by end of July. Average yield 80 kg per plant.

2. Field experiment was conducted during 2013 and 2014 in the research farm of the Chaudhary Charan Singh Haryana Agricultural University Hisar (29.10° N, 75.46° E and 215 m amsl) to assess the heat unit utilization for different phenophases and fruit yield of plum. Three genotypes of plum were planted under high density plantation with spacing of 6 × 6 meters in December and January 2001. The spacing under reference accommodate 277 plants/ha. Pomologists have given different names to the various developmental stages of the temperate fruits. Out of these we have observed only six important phenophases of plum (Fig.1) which were recorded on marked four branches of five trees of each cultivar by visiting the selected tree at two days interval. The meteorological data was collected from the Agromet Observatory situated in the research farm (Fig.2). Following agrometeorological indices, heat use efficiencies were calculated on daily basis and accumulated from bud burst to maturity/harvesting taking 10 °C as base temperature. The dormancy was supposed to be over when the accumulated chilling hours started decreasing.

1. Growing degree days = $[(T_{max} + T_{min})/2] - 10\text{ }^{\circ}\text{C}$
(GDD)
2. Photothermal unit = GDD * Day Length
(PTU)
3. Heliothermal unit = GDD * Sunshine Hours
(HTU)
4. Hydrothermal unit = GDD * RH
(HYTU)

Under the semi arid conditions on an average accumulation of heat units started from January 22nd in 2013 and from January 20th in 2014 when the accumulation of chilling hours started decreasing. The energy use efficiencies were computed (kg/ha/°C) to compare the relative performance of different



Fig. 1. Important phenophases recorded in Pear at Hisar

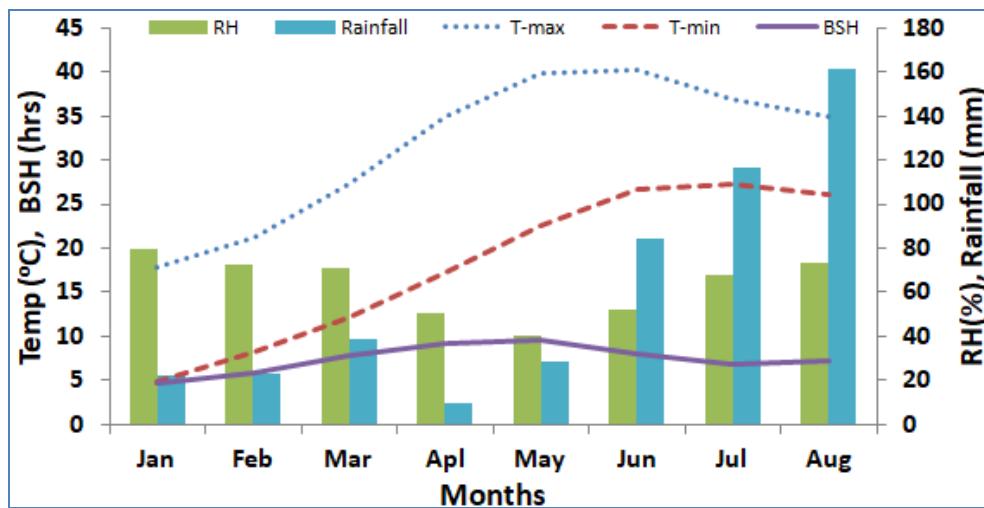


Fig. 2. Weather during the crop growth period (average of two years)
[BSH - Bright sun shine hours, RH - Relative humidity (%) and Temp - Temperature (°C)]

cultivars with respect to utilization of heat units using the following formulae:

1. Heat use efficiency (HUE) = $\frac{\text{Fruit yield (kg ha}^{-1}\text{)}}{\text{GDD } ^\circ\text{C day}}$
2. Photothermal use efficiency (PTUE) = $\frac{\text{Fruit yield (kg ha}^{-1}\text{)}}{\text{PTU } ^\circ\text{C day}}$
3. Heliothermal use efficiency (HTUE) = $\frac{\text{Fruit yield (kg ha}^{-1}\text{)}}{\text{HTU } ^\circ\text{C day}}$
4. Hydrothermal use efficiency (HYTUE) = $\frac{\text{Fruit yield (kg ha}^{-1}\text{)}}{\text{HYTU } ^\circ\text{C day}}$

Phenothermal index (PTI) for each phenophases was calculated as per following formula (Sastry and Chakravarty, 1982). $PTI = \frac{\text{GDD}}{\text{No. of days taken between two phenophases}}$. Predictive regression relation models were also worked out between thermal indices and yield of different root stocks. The plant height, plant girth, annual extension growth, per cent fruit set and physical parameters like fruit weight, fruit length & breadth were also observed for evaluation of performance.

3. *Thermal Indices*: Bud burst of Patharnakh cultivars took place in first week of February and that of Punjab Beauty in second week of February in both the

TABLE 1
Accumulated agrometeorological indices (degree days) to attain different phenophases in pear at Hisar

Phenophases	2013				2014				Mean			
	GDD	PTU	HTU	HYTU	GDD	PTU	HTU	HYTU	GDD	PTU	HTU	HYTU
Patharnakh (PN)												
Bud burst	48.4	261.8	520.7	3649.9	91.4	415.7	982.9	7963.3	69.9	338.8	751.8	5806.6
White bud	85.6	494.1	929.8	6439.0	123.9	639.8	1347.0	10431.9	104.8	567.0	1138.4	8435.4
Full bloom	137.5	816.1	1503.0	10448.5	177.7	976.7	1961.9	15017.1	157.6	896.4	1732.4	12732.8
Fruit set	260.7	1969.6	2944.1	18649.4	280.0	1786.8	3171.0	22864.4	270.3	1878.2	3057.5	20756.9
Maturity	2876.5	23436.4	38385.0	149339.0	2932.2	23228.4	39175.4	163594.2	2904.3	23332.4	38780.2	156466.6
Punjab Beauty (PB)												
Bud burst	72.8	411.9	787.2	5511.9	107.8	504.2	1165.6	9299.6	90.3	458.1	976.4	7405.7
White bud	137.5	816.1	1503.0	10448.5	170.0	938.5	1872.6	14364.5	153.7	877.3	1687.8	12406.5
Full bloom	252.3	1889.8	2847.8	18065.6	262.6	1618.2	2962.0	21675.4	257.4	1754.0	2904.9	19870.5
Fruit set	408.9	3184.6	4735.8	29152.2	430.1	2800.8	4956.2	32960.0	419.5	2992.7	4846.0	31056.1
Maturity	3193.7	25426.5	42697.9	174006.0	3229.5	25048.1	43172.1	185130.5	3211.6	25237.27	42935.03	179568.26

TABLE 2
Days and growth rate to attain different phenophases of pear at Hisar

Phenophases	Patharnakh (PN)				Punjab Beauty (PB)			
	2013		2014		2013		2014	
	Days	Rate	Days	Rate	Days	Rate	Days	Rate
Bud burst	14	0.071	20	0.050	21	0.048	28	0.036
Pink bud	10	0.100	12	0.083	15	0.067	13	0.077
Full bloom	12	0.083	11	0.091	13	0.077	13	0.077
Fruit set	13	0.077	13	0.077	14	0.071	15	0.067
Maturity	125	0.008	126	0.008	136	0.007	135	0.007
Total	174	0.006	182	0.005	199	0.005	204	0.005

years. Days taken to complete growth stages from dormant to bud burst, from bud burst to white-bud and from white-bud to full-bloom were lowest in Patharnakh followed by Punjab Beauty. Similar trend was observed in photothermal units (PTU), heliothermal units (HTU) and hydrothermal units (HYTU).

The data on various thermal units required to completion of various phonological stages from bud burst to maturity are presented in Table 1. The mean of two years of accumulated GDD for Patharnakh cultivar from completion of dormancy to bud burst, white bud, full bloom, fruit set and physiological maturity were 70, 105, 158, 270 and 2904, respectively. Accumulated PTU were

339, 567, 896, 1878 and 23332, respectively. The Accumulated HTU were 752, 1138, 1732, 3058 and 38780, respectively. Similarly accumulated HYTU were calculated as 5807, 8435, 12732, 20757 and 156467 for attaining the growth stage of bud burst, white bud, full bloom, fruit set and physiological maturity, respectively (Table 1). For Punjab Beauty the mean value of accumulated GDD for attaining the recorded five growth stages from the completion of dormancy were 90, 154, 257, 420 and 3212 for bud burst, white bud, full bloom, fruit set and physiological maturity, respectively. PTU were 458, 877, 1754, 2993 and 25237. HTU were 976, 1688, 2905, 4846 and 42935. The HYTU value were calculated as 7406, 12407, 19871, 31056 and 179568, respectively (Table 1).

TABLE 3
Growth rates per day

Phenophases	Patharnakh		Punjab Beauty	
	2013	2014	2013	2014
Bud Burst	0.071	0.050	0.048	0.036
White Bud	0.100	0.083	0.067	0.077
Full Bloom	0.083	0.091	0.077	0.077
Petal Fall	0.077	0.077	0.071	0.067
Maturity	0.008	0.008	0.007	0.007
Life span	0.006	0.005	0.005	0.005

TABLE 4
Phenothermal index (PTI) during various phenological stages of pear at Hisar

Cultivar	Year	Bud burst	White bud	Full Bloom	Fruit set	Maturity	Total
Patharnakh	2013	3.46	3.72	4.33	9.48	20.93	16.53
	2014	4.57	2.72	4.89	7.88	21.05	16.11
	Mean	4.11	3.17	4.60	8.68	20.99	16.32
Punjab Beauty	2013	3.47	4.32	8.83	11.19	20.48	16.05
	2014	3.85	4.78	7.12	11.17	20.73	15.83
	Mean	3.69	4.54	7.98	11.18	20.60	15.94

The growth period of both the cultivars during 2014 was almost one week longer as compared to 2013 which might be due to the fluctuating weather conditions from fruit set to maturity during 2014 and hence, it may be the reason for accumulation of more thermal units for different phenological stage during 2014. Days taken to attain different phenophases by Patharnakh were less and it matured almost 20 days earlier than Punjab Beauty. We can say that Punjab beauty required more thermal time to attain the different phenophases and physiological maturity as compared to Patharnakh (Table 2). The growth rate was higher in case of Patharnakh than Punjab Beauty. The highest growth rate was observed to attain the white bud and full bloom stages in case of Patharnakh (Table 3).

Phenothermal index (PTI): Phenothermal index steadily increased from white bud stage to maturity for both the cultivars but it was formed to decrease for Patharnakh cultivar from bud burst to white bud stage in 2014. It indicates that during 2014 the growth stage from bud burst to white bud took less GDD as compared to other stages in this cultivar of pear. The PTI was lower during 2014 as compared to 2013 for both the cultivars but in respect of the cultivar Patharnakh the mean PTI was

16.32 which more than that of Punjab Beauty. It was highest for both the cultivars from fruit set to maturity stage which is the longest phenophase and during this period (March-July) the accumulation of heat units were higher. On an average the PTI was 4.11, 3.17, 4.6, 8.68 and 20.99 for bud burst, white bud, full bloom, fruit set and physiological maturity, respectively for Patharnakh. The corresponding values of PTI for Punjab Beauty were 3.69, 4.54, 7.98, 11.18 and 20.6 for bud burst, white bud, full bloom, petal fall and physiological maturity, respectively (Table 4).

Thermal use efficiency: The efficiency of thermal, Heliothermal, photothermal and hydrothermal energy conversion for yield and dry matter depend upon genetic factors of crop and time of breaking of bud, after the completion of the rest period. Thermal use efficiency was highest for the cultivar which required lower amount of thermal units for producing higher grain and biological yields. In pear the highest use efficiency (5.1 kg ha⁻¹/GDD days) was observed in cultivar of Patharnakh in 2014 followed by Punjab beauty (3.41 kg ha⁻¹/GDD days) during the same year (Table 5). The utilization efficiency for other indices also followed similar trend.

TABLE 5
Thermal use efficiencies of two genotypes of pear at Hisar conditions

Cultivars	Years	HUE kg ha ⁻¹ / degree day	HTUE kg ha ⁻¹ /degree day	PTUE kg ha ⁻¹ /degree day	HYTUE kg ha ⁻¹ /degree day
Patharnakh	2013	4.078	0.497	0.301	0.082
	2014	5.111	0.632	0.376	0.096
	Mean	4.594	0.565	0.339	0.089
	CV	0.159	0.169	0.156	0.111
Punjab Beauty	2013	2.633	0.330	0.193	0.051
	2014	3.413	0.430	0.250	0.063
	Mean	3.023	0.380	0.222	0.057
	CV	0.182	0.186	0.182	0.149

Among the year of study all thermal use efficiencies are higher in 2014 compared to 2013. On an average the thermal use efficiency in Patharnakh was 4.59 kg ha⁻¹/GDD day with 68 per cent of coefficient of variation. In Punjab beauty it was 3.02 kg ha⁻¹/GDD day with 93 per cent of coefficient of variation. Similar trend was observed for other three thermal use efficiencies in both the cultivars.

Predictive model: Regression models were developed for fruit yield prediction using thermal units consumed during this period. Strong linear regression relationship was observed between fruit yield (FY) and Heat Units (HU). This prediction model holds good for all the other three thermal units (PTU, HTU and HYTU). The equations for forecast of fruit yield are as under:

1. For Patharnakh $FY = 1352 HU + 8616$ ($R^2 = 0.87$)
2. For Punjab Beauty $FY = 904 HU + 6180$ ($R^2 = 0.81$)
3. For Pooled data $FY = 1128 HU + 7398$ ($R^2 = 0.84$)

The Patharnakh showed higher thermal use efficiencies and also showed a better relation in comparison with Punjab beauty and the pooled model.

Thermal indices explained 87% variation in fruit yield of Patharnakh, 81 per cent variation in Punjab beauty. Similar works on developing agroclimatic models based on temperature, photoperiod and day length for mustard (Hundal *et al.*, 2003) for wheat (Hundal *et al.*,

1997) have been reported under Punjab conditions and for apple fruit (Singh and Bhatia, 2011) under mid hill region of Himachal Pradesh.

4. The thermal indices were calculated for two important cultivars of pear taking 10 °C as base temperature. The pear cultivar Patharnakh required 86 GDD, Punjab beauty 137 GDD, to attain the first important phenophase (white bud) after the completion of dormancy. Thermal indices explained more than 81 to 87 per cent variation in fruit yield of pear. In term of plant growth, plant girth, annual extension, fruit set and other physical parameters the performance of Patharnakh was observed to be better followed by Punjab beauty. Both these cultivars were observed precocious and fruiting was recorded in the fifth year after plantation. They are showing better utilization of heat units and hence, suitable for diversification in pear cultivation under changing and prevailing climatic conditions of western Indo Gigantic plain in general and semi arid region of Punjab and Haryana in particular.

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