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Thermal time requirements for phenophases of apple genotypes in Kullu valley

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ABSTRACT

A field experiment was conducted at Horticultural Research Station, Seobag (Kullu) from 2004 to 2010. The phenology of ten apple cultivars was observed on every second day on three plants of each cultivar with three replications from bud-bust, green-tip, pink-bud, full-bloom to physiological maturity. GDD, HTU, PTU, HYTU and heat use efficiency was computed from the meteorological data recorded from observatory and averaged of for ten years. Tydeman, commercial and Mollice has taken lower GDD for the physiological maturity but higher for attaining petal-fall. On an average apple required 330 GDD from bud bust to petal fall with 4°C as base temperature. Cultivars completing the rest period earlier used more thermal units and giving good fruit yields as compare to those breaking their dormancy later. Thermal units explain more than 75-99 % variation in fruit yield. Higher thermal use efficiency was observed for Starking Delicious and Vance Delicious followed by Top Red and Tydeman which may be encouraged among the growers.

Key words: Phenophases GDD, HTU, PTU, HYTU and apple genotype.

The economy of the people of Himachal Pradesh largely depends on apple cultivation and the size of its market in the state which is estimated to be more than Rs. 2200 crore. 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. 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 has been widely used for growth, phenological development and yield of different crops (Rajput *et al.,* 1987; Shanker *et al.,* 1996; Swan *et al.,* 1989). Such works have been done elsewhere (Rao *et al.,* 1999) it has not hitherto been reported from Himachal Pradesh for apple. Hence, the present investigation was carried out to assess the relationship between thermal time, phenophases and fruit yield.

MATERIALS AND METHODS

Field experiment was conducted during 2004-2010 in the research farm of the Dr. YS Parmar University of Horticulture & Forestry located at HRS, Kullu (32°N, 77°E and 1350 m amsl) to assess the thermal time requirements for different phenophases of ten apple genotypes planted in 1991. Pomologists have given names to the various developmental stages of the apple however, we observed only five important phenophases vz. green tip, pink bud, full bloom petal fall and maturity which were recorded by visiting the field at two days interval. Daily weather data was collected from Agromet Observatory situated in the same farm. Different agrometeorological indices and thermal use efficiencies were calculated on daily basis and accumulated from bud burst to maturity.

Growing degree days (GDD) = (Tmax +Tmin)/2-4°C

Photothermal unit (PTU) = GDD * Day Length

Heliothermal unit(HTU) = GDD * Sunshine Hours

Hydrothermal unit (HYTU) = GDD * RH

The energy use efficiencies were computed ((kg ha^{-1} per degree) to compare the relative performance of different cultivars with respect to utilization of heat using the following formulae:

Heat use efficiency (HUE) = Fruit yield (kg ha^{-1})/GDD °C day.

Photothermal use efficiency (PTUE) = Fruit yield (kg ha^{-1}) /PTU °C hour.

Heliothermal use efficiency (HTUE) = Fruit yield (kgha^{-1})/HTU °C hour.

Hydrothermal use efficiency (HYTUE) = Fruit yield (kg ha^{-1})/HYTU °C day %

Phenothermal index (PTI) for each phenophases was calculated as per following formula (Sastry and Chakravarty,

Table 1: Accumulated thermal units to attain various phenophases in apple cultivars

	Green-tip	Pink-bud	Full-bloom	Petal-fall	Maturity
			GDD		
Starking	94	194	266	376	2847
Vance	94	193	271	381	2852
Top Red	94	193	271	381	2852
Oregon Spur	94	193	271	381	2852
Red Chief	94	193	271	381	2852
Red Spur	94	193	271	381	2852
Starkrimson	94	193	271	381	2852
Tydeman	96	210	306	409	2380
Commercial	96	191	264	366	2337
Mollice	94	193	271	381	2250
Mean	94	195	273	382	2693
			PTU		
Starking	1109	2309	3188	4568	38671
Vance	1099	2296	3248	4627	38731
Top Red	1099	2296	3248	4627	38731
Oregon Spur	1099	2296	3248	4627	38731
Red Chief	1099	2296	3248	4627	38731
Red Spur	1099	2296	3248	4627	38731
Starkrimson	1099	2296	3248	4627	38731
Tydeman	1137	2516	3706	5019	32405
Commercial	1119	2261	3143	4427	31812
Mollice	1099	2296	3248	4627	30607
Mean	1106	2316	3277	4641	36588
			HTU		
Starking	389	1264	1820	2435	15113
Vance	389	1264	1820	2435	15113
Top Red	389	1264	1820	2435	15113
Oregon Spur	389	1264	1820	2435	15113
Red Chief	389	1264	1820	2435	15113
Red Spur	389	1264	1820	2435	15113
Starkrimson	389	1264	1820	2435	15113
Tydeman	452	1375	1928	2546	13479
Commercial	389	1126	1662	2281	13213
Mollice	389	1264	1820	2435	13002
Mean	395	1261	1815	2431	14548
			HYTU		
Starking	4437	9123	12673	17994	156742
Vance	4416	9064	12904	18226	156974
Top Red	4416	9064	12904	18226	156974
Oregon Spur	4416	9064	12904	18226	156974
Red Chief	4416	9064	12904	18226	156974
Red Spur	4416	9064	12904	18226	156974
Starkrimson	4416	9064	12904	18226	156974
Tydeman	4386	9947	14631	19545	125135
Commercial	4591	8928	12526	17569	123160
Mollice	4416	9064	12904	18226	116534
Mean	4432	9145	13016	18269	146342

Table 2: Photothermal index (PTI) during various growth stages

	Green-tip	Pink-bud	Full-bloom	Petal-fall	Maturity
Starking Delicious	9.32	11.28	12.18	13.22	16.88
Vance Delicious	9.24	11.14	12.42	13.12	16.88
Top Red Delicious	9.43	10.93	12.18	13.25	16.88
Oregon Spur	9.34	11.24	12.15	12.92	16.81
Red Chief	9.34	11.22	12.23	12.92	16.81
Red Spur	9.34	11.24	12.15	12.92	16.81
Starkrimson	8.98	11.14	12.16	12.76	16.81
Tydeman' Early Worcester	9.73	11.44	13.34	13.69	16.12
Commercial	8.84	11.06	12.02	12.45	13.44
Mollice Delicious	9.40	11.17	12.66	13.41	15.32
Mean	9.31	11.22	12.31	13.14	16.33
CV %	2.61	1.23	3.23	2.71	6.90

Table 3: Thermal use efficiencies

	HUE	PTUE	HTUE	HYTUE
Starking Delicious	6.83	0.51	1.31	0.13
Vance Delicious	6.21	0.46	1.19	0.11
Top Red Delicious	5.17	0.39	0.99	0.10
Oregon Spur	4.68	0.35	0.89	0.09
Red Chief	4.94	0.37	0.95	0.09
Red Spur	4.18	0.31	0.80	0.08
Starkrimson	4.07	0.30	0.78	0.08
Tydeman's Early Worcester	5.12	0.38	1.92	0.10
Commercial	4.22	0.32	0.77	0.08
Mollice Delicious	4.15	0.31	0.74	0.08
Mean	5.00	0.40	0.90	0.10
CV %	18.8	18.7	20.17	17.8

1982).

PTI = (GDD)/No. of days taken between two phenophases. Predictive regression relation model was also worked out between thermal indices and yield of different cultivars.

RESULTS AND DISCUSSION

Thermal indices

Days taken to complete growth stages from dormant to green-tip, from green-tip to pink-bud and from pink-bud to full-bloom decreased in all the cultivars except Tydeman, Commercial and Mollice. The accumulated GDD to reach various growth stages did not show appreciable variation among the cultivars (Table 1). Similar trend was observed for photothermal units (PTU), heliothermal units (HTU) and hydrothermal unit (HYTU). The GDD were least and HTU were most variable among the ten cultivars during the green-tip. To attain maturity Mollice required less numbers of thermal units followed by Commercial and Tydeman (Table 1). For the first three stages i.e. green-tip, pink-bud and full-bloom Tydeman required higher numbers of all thermal units but, Commercial required least numbers of thermal units for all the phenophases. On an average apple required 95 GDD, 1106 PTU, 395 HTU and 4432 HYTU to attain green-tip after bud break; 195 GDD, 2315 PTU, 1261 HTU and 9145 HYTU from green tip to pink bud; 273 GDD, 3277 PTU, 1815 HTU and 13016 HYTU from pink bud to full bloom; 382 GDD, 4641 PTU, 2430 HTU and 18269 HYTU from full bloom to petal fall and 2693 GDD, 36588 PTU, 14548 HTU & 146341 HYTU from petal fall to attain the maturity.

Phenothermal index (PTI)

Phenothermal index increased till maturity in all the cultivars (Table 2). The highest PTI was observed in Top Red for green-tip, in Tydeman for pink-bud, in Vance for full-bloom, again in Tydeman for petal-fall and in first three cultivars (Starking Delicious, Vance Delicious and Top Red) for maturity. The coefficient of variation among the ten genotypes was highest for maturity and lowest for pink-bud. On an average the PTI was 9, 11, 12, 13, and 16 for the five

observed phenophases for apple.

Thermal use efficiencies

The efficiency of thermal energy, photothermal energy and hydrothermal energy conversion for yield and dry matter depend upon genetic factors of crop and the time of breaking of bud after the completion of the rest period. Thermal use efficiencies were highest for the cultivars which have taken higher thermal units. Starking and Vance Delicious having highest (>6) efficiency followed by Top Red and Tydeman (>5) and rest cultivars also having good thermal use efficiencies of more than four (Table 4). Heliothermal use efficiency was observed highest for Tydeman and lowest for Mollice followed by Commercial.

Predictive model

Regression model was developed for fruit yield prediction taking average yield of all the ten varieties for three years and thermal units consumed by them during this period. Strong and linear regression relationship was observed between fruit yield (FY) and thermal units (TU). This prediction model holds good for all the four (GDD, PTU, HTU and HYTU) thermal units.

$$FY = -1.01\ TU + 19.2 \qquad (R^2 = 0.88)$$

Starking Delicious and Vance Delicious having higher photothermal use efficiency (>6) as compared with others. They have been analyzed separately and prediction models developed for them showing more better relation in case of Vance Delicious ($R^2 = 0.99$) than Starking Delicious ($R^2 = 0.75$) and the pooled model for all the varieties.

For Vance Delicious $FY = -0.0047\ TU + 31.99$ ($R^2 = 0.99$)

For Starking Delicious $FY = -0.0052\ TU + 35.1$ ($R^2 = 0.75$)

The study shows that thermal units explained the 88 % variation in fruit yield of apple genotypes under varied thermal regimes.

CONCLUSIONS

Apple required 95 GDD to attain the first important phenophases (green-tip) after bud break keeping 4° C as base temperature. Cultivars completing the rest period earlier used more thermal units and giving good fruit yields as compare to those breaking their dormancy later. Thermal units explained more than 75-99 % variation in fruit yield. Starking Delicious and Vance Delicious cultivars were showing better utilization of thermal units so they may be popularized among the orchardists for better and stable apple production.

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