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Research Paper

Pheno-thermal response of exotic high density apple varieties under temperate conditions of Kashmir

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ABSTRACT

The present study evaluated the effect of mean temperature and rainfall on phenology attainment of twenty cultivars of apple grown temperate region of Kashmir, India during 2018 and 2019. The results showed that increase in accumulated heat units decreased the time for attainment of phenological stages. The minimum requirement of heat units were recorded in Elstar (17 day ^{0}C), Jona gold (18 day ^{0}C) and Red braeburn (18 day ^{0}C) for attainment of silver tip stage while as dormancy break was recorded earliest in cv. Red braeburn and Red velox. The attainment of pink bud stage was recorded earliest in Red delicious followed by Elrosa and Gala redlum. However, fruit setting was found earlier in cv. Jona gold (50.1 day ^{0}C) and late in Gala redlum and Gala mast. Highest heliothermal units were found in cv. Gala Mast (478 day ^{0}C h) and Braeburn (461 day ^{0}C h) and lowest in Jona gold (336 day ^{0}C h) while as maximum hydrothermal units were found in Gala red (484 day ^{0}C h) and Gala mast (471 day ^{0}C h). Yield and yield associated traits were also found significantly influenced by accumulated heat units with maximum yield recorded in cv. Golden clone B (90.54 t ha^{-1}) followed by Gala redlum (75.93 t/ha) and Red chief (71.13 t ha^{-1}) with maximum heliothermal use efficiency (0.22), heat use efficiency (1.46) and hydrothermal use efficiency (0.22), respectively.

Key words: Apple, phenophases, temperature, climate, agro-meteorological indices

Apple (*Malus domestica) is* an important temperate fruit crop belongs to family Rosaceae and is known to mankind from pre-historic times. The phenology of apple has changed with the climate change. The introduction of new varieties and rootstocks for high-density plantations (3000-4000 plants/ha), different information related to yield, tree growth, and fruit quality of apple varieties is still lacking (Singh *et al.,* 2017). Since the phonological development of a plant involves several developmental changes in a plant at various stages. Climate change is one of the natural endowments that almost are unchangeable thus the selection and planting of species/varieties with maximum correlation with climate change is of paramount importance. Knowledge of planting stage and fruit growth development are important requirements for crop management. The appearance dates of plant phenophases provide the basic information for the decision to the farmers as regards to some cultivation techniques such as fertilizers, irrigation and crop protection practices. This knowledge can help the selection of most suitable species or varieties of fruit trees for obtaining better fruit yield as well as quality. Temperature is one of the most important elements of climate change which directly affects the productivity levels. Thermal time affect has been described as an independent variable to delineate plant growth and development (Dwyer and Stewart, 1986). Temperature based agromet indices are linearly related to temperature in the range between base and optimum temperatures. (Monteith, 1981).The use of thermal unit system or Growing Degree Day (GDD) is another way to access the winter actions between the climate and plant, hence it becomes important to investigate the observed changes in the phenology and GDD so that the future predictions can be validated. The High density plantation of apple being in infancy in the region and as such no significant work has been done on the agro-met aspects of this crop. The present study was conducted to analyze various phenological stages and thermal time of twenty one varieties of apple in Kashmir region, India.

MATERIAL AND METHODS

A field experiment was conducted at experimental field of Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Shalimar Campus, Srinagar, India, which falls in the

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Table 1: Phenophase wise heat units required (day ^{0}C) in apple cultivars under temperate Kashmir conditions (Pooled data)

Variety/Cultivar	Bud break	Silver tip	Green tip	Leaf out	Pink bud	Initial bloom	Full bloom	Petal fall	Fruit set
Mitch gala	41.4	22.3	30.5	47.4	109.2	57.3	86.0	38.8	125.8
Fuji ZehnAzetac	91.2	38.6	36.5	81.5	87.5	38.5	77.3	115.7	140.8
Golden Clone B	114.5	32.8	31.8	91.8	75.2	35.8	94.8	101.2	104.8
Red Braeburn	36.5	16.8	32.7	35.9	104.0	57.0	72.4	44.0	51.8
Super Chief Sandidge	80.7	33.9	32.8	78.5	92.8	36.7	83.6	128.0	80.2
Gala Redlum	75.5	31.1	23.3	60.3	115.0	40.9	64.1	93.5	179.0
Red Velox	36.5	52.2	03.3	49.8	80.5	57.5	58.8	91.5	272.5
Golden Delicious Reinders	71.9	21.2	47.4	40.5	103.7	43.5	83.7	41.0	116.0
Red chief	46.5	22.4	31.1	32.0	99.3	57.0	23.8	86.2	71.8
Elrosa	65.5	21.0	13.2	50.3	105.0	30.9	54.1	83.6	168.0
Jona Gold	46.5	18.3	53.8	51.8	81.5	64.8	61.2	36.3	17.8
Red Delicious	68.7	20.2	52.6	27.8	104.5	55.5	55.4	35.6	59.3
Elstar	68.7	17.9	41.1	35.0	114.0	47.8	36.7	62.1	138.0
Wilston Star	65.3	16.1	38.8	33.2	110.1	43.3	34.2	59.4	130.0
DecosteRobinjin	46.5	22.3	45.8	51.8	81.50	64.8	42.7	95.8	52.5
Red Jonaprince	41.5	19.3	30.5	47.4	105.2	64.8	42.7	95.8	39.5
Pinnova	41.45	60.7	98.8	156.6	209.2	294.7	365.9	450.9	417.2
Braeburn	202.2	259.8	312.5	373.6	438.7	490.4	597.9	707.5	838.7
Gala Red	68.7	91.2	106.5	147.2	247.7	326.2	373.6	476.4	767.7
Gala Mast	55.1	80.3	116.1	151.1	277.1	329.5	360.2	445.3	626.3

Table 2: Phenophase wise heliothermal units required (day ^{0}C h) in apple cultivars under temperate conditions (Pooled data)

Variety /Cultivars	Bud break	Silver tip	Green tip	Leaf out	Pink bud	Initial bloom	Full bloom	Petal fall	Fruit set
Mitch gala	128	93	158	265	633	342	576	270	900
Fuji zehn azetac	282	162	189	456	507	229	517	808	1008
Golden clone B	355	137	165	513	435	213	635	707	750
Red braeburn	113	70	170	200	603	340	485	307	370
Super chief sandidge	250	142	170	439	538	219	559	894	574
Gala redlum	233	130	120	337	667	244	429	653	1281
Red velox	113	219	116	278	466	343	393	639	1951
Golden delicious reinders	223	89	246	226	601	260	560	286	830
Red chief	144	93	161	179	575	340	159	602	514
Wilston star	134	85	156	168	557	324	134	580	491
Elrosa	202	88	68	281	609	185	362	584	1202
Jona gold	144	76	279	289	472	387	409	253	127
Red delicious	213	84	273	155	606	331	371	248	424
Elstar	213	75	213	196	661	285	245	433	988
Decoste robinjin	144	93	238	289	472	387	285	669	375
Red Jonaprince	128	80	158	265	610	387	285	669	282
Pinnova	128	254	513	877	1213	1762	2451	3151	2987
Braeburn	626	1091	1625	2092	2544	2932	4005	4945	6005
Gala red	213	382	553	824	1436	1950	2503	3330	5496
Gala mast	170	337	603	846	1607	1970	2413	3112	4484

temperate zone. It is located at 34°9′66′′N latitude and 74°52′34′′E longitude and 2,000 m above mean sea level. The climate of the study area is moderately hot during summer to very cold during the winter season and minimum temperature goes up to (-)10^{o}C during winter season. The average rainfall in the region varies from 900-1200 mm. The experiment was conducted during 2018 and 2019 years at experimental orchard with 20 varieties of apple grown as high density plantations during different period. Phenophase durations were recorded at different time intervals. To record the duration of every phenophase, four random shoots were selected in all the directions from randomly selected plants from each variety. Different agro-meteorological indices and heat use efficiencies were calculated on daily basis and accumulated from bud burst to maturity/harvesting taking 4^{0}C as base temperature which is most suitable. The daily weather data with respect to maximum and minimum temperature, sunshine hours, relative humidity and rainfall for the two years was collected from Agromet Field Unit, SKUAST-K, Shalimar, Srinagar. The dormancy period was started from December and ends when the accumulated chilling hours start decreasing and accumulation of heat begins. The agrometeorological

Table 3: Phenophase wise hydrothermal units required (day ^{0}C %) in apple cultivars under temperate conditions (Pooled data)

Variety / Cultivar	Bud break	Silver tip	Green tip	Leaf out	Pink bud	Initial bloom	Full bloom	Petal fall	Fruit set
Mitch gala	3780	2007	2655	4036	8954	4566	6199	2712	8177
Fuji ZehnAzetac	8313	3482	3183	6947	7170	3066	5572	8099	9152
Golden Clone B	10443	2954	2768	7820	6162	2851	6834	7084	6812
Red Braeburn	3324	1511	2851	3055	8528	4546	5219	3080	3367
Super chief sandidge	7356	3053	2856	6691	7605	2923	6023	8960	5213
Gala redlum	6881	2801	2027	5135	9430	3262	4617	6545	11635
Red velox	3329	4709	283	4245	6601	4586	4235	6401	17712
Golden delicious reinders	6562	1912	4129	3452	8503	3469	6033	2870	7540
Red chief	4236	2016	2707	2727	8138	4546	1712	6030	4667
Elrosa	5969	1897	1154	4283	8610	2467	3897	5852	10920
Jona gold	4236	1646	4691	4411	6683	5164	4408	2541	1153
Red delicious	6266	1822	4587	2365	8569	4426	3993	2488	3851
Elstar	6266	1619	3584	2983	9348	3808	2642	4343	8970
Wilston star	5432	1432	3217	2876	9265	3719	2549	4240	8876
Decoste robinjin	4236	2007	3994	4411	6683	5164	3074	6706	3412
Red jonaprince	3780	1736	2655	4036	8626	5164	3074	6706	2567
Pinnova	3780	5475	8612	13348	17154	23505	26377	31563	27118
Braeburn	18442	23432	27253	31845	35973	39114	43102	49525	54515
Gala red	6266	8222	9287	12547	20311	26017	26932	33348	49900
Gala Mast	5021	7239	10125	12879	22722	26280	25966	31171	40709

Table 4: Phenophase wise hydrothermal units required (day ^{0}C h) in apple cultivars under temperate conditions (Pooled data)

Variety / Cultivar	Bud break	Silver tip	Green tip	Leaf out	Pink bud	Initial bloom	Full bloom	Petal fall	Fruit set
Mitch gala	207	111	182	284	764	400	688	310	1006
Fuji zehn azetac	455	193	219	489	612	269	618	925	1126
Golden clone B	572	163	190	550	526	250	758	809	838
Red braeburn	182	83	196	215	728	399	579	352	414
Super chief sandidge	403	169	196	471	649	256	668	1024	641
Gala redlum	377	155	139	361	805	286	512	748	1432
Red velox	182	261	19	298	563	402	470	731	2180
Golden delicious reinders	359	106	284	243	725	304	669	328	928
Red chief	232	111	186	192	694	399	190	689	574
Wilston star	216	101	180	180	672	380	160	663	549
Elrosa	327	105	79	301	735	216	432	668	1344
Jona gold	232	91	322	310	570	453	489	290	142
Red delicious	343	101	315	166	731	388	443	284	474
Elstar	343	89	246	210	798	334	293	496	1104
Decoste robinjin	326	80	232	199	770	303	273	475	1040
Red jonaprince	232	111	274	310	570	453	341	766	420
Pinnova	207	96	182	284	736	453	341	766	316
Braeburn	207	303	592	939	1464	2062	2927	3607	3337
Gala red	1011	1298	1875	2241	3070	3432	4783	5660	6709
Gala mast	343	455	639	883	1733	2283	2988	3811	6141

indices i.e. growing degree days (GDD), photothermal unit (PTU), heliothermal unit and Hydrothermal unit (HYTU) were calculated using Sastry and Chakravarty, (1982), given as

Growing Degree Days (GDD) = $\sum(T_{max}+T_{min})/2 - T_b$

where T_{max} is daily maximum temperature(^{0} C), T min is daily minimum temperature(^{0}C), and Tb is base temperature of apple =4 ^{0} C

Photo thermal unit (PTU) = GDD*Day length

Helio-thermal Unit (HTU) = GDD*Sunshine hours

Hydrothermal unit (HYTU) = GDD*RH

The heat units were taken from the day when their accumulation starts increasing and the chilling hour's starts decreasing as suggested by various researchers (Singh and Bhattia, 2012; Singh *et al*., 2015). In Kashmir region, heat units started accumulating from January onwards hence GDD was calculated accordingly during both the years. The energy use efficiencies *viz* heat use efficiency (HTU), Photothermal use efficiency (PTUE), Heliothermal use efficiency (HTUE), Hydrothermal use efficiency (HYTUE), Phenothermal Index (PTI) were computed (kg h^{-1} ^{0}C)

Table 5 : Yield and energy use efficiencies of apple cultivars under temperate Kashmir conditions (pooled data)

Variety /Cultivar	Yield (kg/tree)	Yield (t ha^{-1})	Helio-thermal use efficiency	Heat use efficiency	Hydrothermal use efficiency
Mitch gala	16.80	50.40	55.95	0.44	0.68
Fuji zehn azetac	29.20	87.60	86.89	0.61	0.94
Golden clone B	30.18	90.54	120.66	1.15	1.77
Red braeburn	14.00	42.00	113.24	2.18	3.36
Super chief sandidge	16.90	49.80	86.72	1.08	1.66
Gala redlum	25.31	75.93	59.24	0.33	0.50
Red velox	12.50	37.50	19.21	0.07	0.10
Golden delicious reinders	17.60	52.80	63.57	0.54	0.84
Red chief	23.71	71.13	138.36	1.92	2.96
Wilston star	7.24	21.72	44.17	0.64	0.98
Elrosa	10.12	30.36	25.23	0.15	0.23
Jona gold	10.28	30.84	242.66	13.67	21.03
Red delicious	12.11	36.33	85.63	1.44	2.22
Elstar	10.51	31.53	31.91	0.23	0.35
Decoste robinjin	9.82	29.87	30.02	0.61	0.29
Red jonaprince	9.82	29.46	104.16	1.15	4.05
Pinnova	8.18	24.54	8.21	2.18	0.03
Braeburn	14.10	42.30	7.04	1.08	0.01
Gala red	14.00	39.80	54.65	2.03	0.59
Gala mast	14.80	49.32	68.92	1.96	0.55

using the following formulae:

Heat use efficiency (HTU) = fruit yield (kg ha^{-1})/GDD ^{0}C day

Photothermal use efficiency (PTUE) = fruit yield (kgha^{-1})/PTU^{0}C day

Heliothermal use efficiency (HTUE)= fruit yield (kgha^{-1}) /HTU^{0}C day

Hydrothermal use efficiency (HYTUE) = fruit yield (kg ha^{-1}) / HYTU^{0}C day

Phenothermal Index (PTI) for each phenophase was calculated as per the following formula (Sastry and Charavarty, 1982)

PTI= (GDD)/ No. of days taken between two phenophases.

RESULTS AND DISCUSSION

The phenology of twenty varieties of apple grown under high density plantation was analyzed. The meteorological data for the two experimental years indicates that the increase in maximum and minimum monthly temperatures with decrease in precipitation result in change in stage of the apple varieties. With the increases in minimum temperature (sub zero) especially from March onwards, the plant attains heat units leading to breakage of dormancy and change in phenophases. Increase in accumulated heat units among the varieties decreased the length of phenophase attainment.

Agrometeorological indices

The results suggested a remarkable variation in attaining each phenological stage in different cultivars of apple. Bud burst in all the genotypes took place during the month of February during study period. The requirement of cumulative heat units varied with each phenological stage and with each cultivar. The number of growing degree days (GDD) in apple genotypes is shown in Table 1. It is evident from Table 1 that for completion of dormancy and beginning of bud burst, cv. Red braeburn required 36.5 day ^{0}C followed by cv. Red velox (36.5 day^{0}C), Pinnova (41.2 day ^{0}C) and Red jonaprince (41.5 day ^{0}C), respectively. The helio-thermal unit index (day ^{0}C h) in apple genotypes has been shown in Table 2. The minimum requirement of heliothermal units were observed to attain the silver tip stage in cv. Wilson star (16 day ^{0}C hr), Red Braeburn (16 day ^{0}C h), Elstar (17 day ^{0}C h) followed by Jona gold (18 day ^{0}C h).The variation in number of days and GDD required for silver tip stage amongst different cultivars was due to the amount of chilling hours required and the threshold temperatures to break dormancy period which vary between the cultivars whereas cultivars with low chilling requirement tend to have a bud break at lower temperatures. Similar results of varying heat unit requirement at different developmental stages were also given by Jackson (2003). The calendar days, taken to attain the pink bud stage also varied among the cultivars.

The hydrothermal units in apple genotypes are illustrated in Table 3. The number of heat units taken to accomplish the pink bud stage varied from 3324 to 18442 day ^{0}C % with earliest days recorded in cv. Red braeburn followed by Red velox (3329 day ^{0}C %), Mitch gala, Red janoprince and Pinnova (3780 day ^{0}C %) followed by Elrosa, Gala Redlum and Super Chief sandidge. Braeburn took highest number of heat units in terms of hydrothermal units (18442 day ^{0}C %). In this stage the high temperature resulted in higher accumulation of GDD leading to earlier occurrence of green tip stage in cultivars with higher requirement of temperatures for breaking dormancy. Donelly *et al.* (2004) have also attributed the significant role of air temperatures in influencing the seasonal timing of spring phenophases related to foliage and flowering of

various plant species. From the data, it is also clear that fruit setting was recorded earlier in cv. Jona Gold (17 day ^{0}C h), and highest by Baerbun (838 day ^{0}C h) Helio-thermal units for fruit set also varied significantly among cultivars with values ranging from 127 to 6005 (day ^{0}C h). The accumulated heliothermal units were higher at fruit setting in Braeburn, and lowest in Jona gold (127 day ^{0}C h) while as hydrothermal units were in between 1153 to 54515 (day ^{0}C h) with lowest value recorded in Jona gold and highest in Braebrun cultivar.

The photothermal units used for attaining different phenophases is summarized in Table 4. Photothermal units (PTU) were also calculated for all the varieties by multiplying GDD with day length. It is evident from Table 5 that PTU was found highest in Gala Red (6709 day^{0}C h) and Gala Mast (6141 day^{0}C h) and lowest in Jona Gold (142 day^{0}C h) among all cultivars.

Energy use efficiencies

The efficiency of thermal, heliothermal, photothermal and hydrothermal energy conversion for yield and dry matter is dependent upon genetic makeup of crop and time required to break dormancy and to complete the rest period. Heat use efficiency (HUE) is important factor in crop development and is influenced by the environment. The yield and use efficiency of apple genotypes is summarized in Table 5. The heat use efficiency of apple cultivars was found to be higher in Jona gold (13.67) and lowest in Red vilox (0.07) which means lower amount of thermal units were required to produce higher grain and biological yield. Thus planting of early varieties seems to be essential for harnessing heat use efficiency under changing environmental conditions (Rajput, 1980).

The cultivar characteristics and differing air temperature led to the variation in calendar days for achieving each phonological/ developmental stage. The variation among different apple cultivars is attributed to their varied chilling requirements and sensitivity to temperatures. The cultivars also accumulated lower heat units with higher requirement of chilling as compared to cultivars with higher requirements of chilling. Hanke *et al.* (2007) stated that alteration in exogenous factors such as chilling temperature during the winter season resulting in the variation in flower bud formation. A variation of about 48-50 % was observed in accumulated GDD for fruit setting in different cultivars of apple. The genotype and environment interaction played an important role, thus fewer days are required for fruit setting in cultivars *viz*., Jona Gold, Red braeburn and Red chief which have resulted in earlier fruit set in these cultivars. The results indicated that the maximum fruit yield of 30.18 kg/tree (90.54 t ha^{-1}) was recorded in golden clone B followed by Fuji Zehn Azetac 29.20 kg/tree (87.6 t ha^{-1}), respectively while as lowest fruit yield was recorded in Wilston star with 7.24 kg/tree (21.72 t ha^{-1}), respectively.

CONCLUSION

The use of agro-meteorological indices in high density plantation of apple provides scientific basis for finding out the influence of weather parameters on attainment of various crucial phenophases of twenty exotic cultivars right from bud break to fruit maturity stage. The results evidently depicted stage wise relation of temperature, with phenophases and their attainment. Accumulation of thermal units, heliothermal, hydrothermal units and photo thermal units appeared to be lesser during initial stages/phenophases. The performances of cv's. Elrosa, Gala Redlum and Golden clone B were found comparatively better in terms of utilization of heat units/efficient and hence, more suitable for diversification in apple cultivation in the region. These results may further be used effectively to predict different phenophases for consequent management hence, apple production may be ascertained under changing climatic scenarios of Kashmir region.

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REFERENCES

Donnelly,A., Mike, B.J and John, S. (2004). A review of indicators of climate change for use in Ireland. *Int. J. Biometeorol*. 49:1-2.

Dwyer, L.M. and Steward,D.W.(1986).Leaf area development in field grown Miaze. *Agron. J*., 78:334-348.

Hanke, M.V., Flachowsky,H., Petil, A., Hattasch, C.(2007). No flower No fruit-Genetic potentials to trigger flowering in fruit trees. *Genes,Genomes and Genomics* 1(1):1-20.

Jackson, J.E. (2003).The biology of Apples and Pears.New York USA:Cambridge University Press 488.

Monteith, J.L. (1981).Climate variation and growth of crops. *Quart J. Royal Meteorol. Soc.,*107:602-607.

Rajput,R.P.(1980). Response of soybean crop to climate and soil environments. Unpublished Ph.D Thesis, IARI, New Delhi, India.

Sastry, P.S.N. and Chakravarty, N.V.K. (1982). Energy summation indices for wheat crop in India. *Agric. Meteorol* 27:45-48.

Singh, P., Kumar, S. and Dadhich, S. (2017). Impact of climate variability on the production and productivity of maize (Zea mays l)in north western Himalayan region, India. *J.Agrometeorol*.,19 (Spl Issue): 338-44.

Singh,M. and Bhatia.H.S. (2012).Thermal indices in relation to crop phenology and fruit yield of Apple. *Mausam,* 63 (3), 449-454.

Singh, M, Niwas, R., Godara, A.K. and Khichar, M.L. (2015). Pheno-thermal response of plum genotypes. *J Agrometeorol.,* 17 (2) : 230-233.