Journal of Agrometeorology 17 (2) : 230-233 (December 2015)

Pheno-thermal response of plum genotypes in semi arid region of Haryana

MOHAN SINGH, RAM NIWAS, A.K.GODARA[1] and M.L. KHICHAR

Department of Agricultural Meteorology, [1]Department of Horticulture
CCS Haryana Agricultural University, Hisar – 125004 (Haryana)
E-mail: jangra_ms@live.com

ABSTRACT

Plum prefers temperate climate however, it has been found growing from higher hills in Srinagar to Jaipur in Rajasthan. Kala Amritsari, Satluj Purple and Titron cultivars of plum planted at experimental orchard of CCS Haryana Agricultural University, Hisar farm in the year 2001 on which the present study was done during the year 2013-14. The overall growth was observed better in Kala Amritsari followed by Satluj purple and Titron which is a late maturing variety. The thermal time required by Kala Amritsari and Satluj Purple was at par but the Titron required more thermal indices. The heat use efficiency was observed highest for Kala Amritsari and lowest for Titron whereas the photothermal index was highest in Titron followed by Kala Amritsari and Satluj Purple. The thermal units explained the 94 per cent variation in fruit yield of Kala Amritsari, 87 per cent variation in Satluj Purple and 83 percent variation in fruit yield of Titron cultivar.

Key words: Plum, phenophases, temperate climate, thermal time, heat use efficiency

Plum is native to China, although it became a commercial fruit of Japan and America. It is known as Japanese plum (*Prunus salicina* Lindell) due to its cultivation in Japan from where cultivars spread to other places. At present, plum is cultivated in all temperate climate countries of the world including India. It has been found the growing from higher hills in Srinagar to Jaipur in Rajasthan and areas around Delhi. It is successfully grown in semi arid region of Haryana also. It requires less chilling hours and can tolerate frost and high summers both, that is why it can be cultivated in both low temperatures to 0°C and up, highest up to 47°C in summers. It may also be planted as a filler fruit plant in orchards due to low chilling requirement and less juvenile period. Plums are highly productive due to profuse flowering, high fruit set and early ripening habit of cultivars recommended for plains. The major cultivars of plum grown in plain area of Haryana and Punjab state are Kala Amritsari, which is a self-fruitful high yielding local cultivar and is most preferred cultivar of plains. Its fruits are of medium size, round oblate depressed at both ends, which ripen in second half of May month. The cultivar Satluj Purple is a self-unfruitful cultivar and requires pollinizer for good fruit set. Tree is medium in vigor with upright habit of growth. It is an early ripening low yielding cultivar. Titron is a self-fruitful cultivar but its yield increases if Alucha Early Round is used as a pollinizer. Titron trees are smaller than Kala Amritsari.

The plum tree remains in dormancy during the months of December and January and bud beak takes place from first week of February after completing the chilling requirements under Haryana conditions. 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. 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 Thermal Time/Growing degree days, Photothermal unit, Heliothermal unit and Hydrothermal units 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 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 semi arid region of Haryana especially on fruit crops. Hence, the present investigation was carried out to assess the response of phenology and fruit yield of plum cultivars growing degree days and heat unit utilization under semi arid conditions.

MATERIALS AND METHODS

Field experiment was conducted during the year 2013 and 2014 at experimental orchard of CCS Haryana Agricultural University Hisar (29.10°N, 75.46°E and 215 m msl) to assess the heat unit utilization for different phenophases of 13 years old three genotypes of plum planted at spacing of 6x6 meters. The spacing under reference accommodate 277 plants ha^{-1}. Pomologists have given different names to the various developmental growth stages of plum fruits tree. Out of these we have observed only six important phenophases of plum, which were recorded on marked four branches of five trees of each genotype by visiting the selected tree at two days interval. The meteorological data was collected from the Agromet Observatory situated in the research farm of the University. Following agrometeorological indices and heat use efficiencies were calculated on daily basis and accumulated from bud burst to maturity/harvesting taking 10° C as base temperature. The life span of plum was divided into two seasons (i) effective growing season from February to November and (ii) dormant season from December to January in Hisar conditions. The dormant period was supposed to be over when the accumulated chilling hours started decreasing and accumulation of heat units begins.

1. Growing degree days (GDD) = [(Tmax +Tmin)/2]- 10° C
2. Photothermal unit (PTU) = GDD * Day length
3. Heliothermal unit (HTU) = GDD * Sunshine hours
4. Hydrothermal unit (HYTU) = GDD * RH

The heat units were counted from the day when their accumulation starts increasing and the chilling hours start decreasing (Singh and Bhatia, 2011). In Hisar conditions during the dormant period the accumulation of heat units decreasing continuously up to January, 22 in 2013 and January, 20 in 2014. From these dates accumulation of heat units started and hence, growing degree days were calculated from the next day i.e. January 23, in 2013 and January 21 in 2014, respectively. 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 unit using the following formulae:

1. Heat use efficiency (HUE)
   = Fruit yield (kg ha^{-1})/GDD °C day.
2. Photothermal use efficiency (PTUE)
   = Fruit yield (kg ha^{-1})/PTU °C day.
3. Heliothermal use efficiency (HTUE)
   = Fruit yield (kgha^{-1})/HTU °C day.
4. 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, 1982).

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

RESULTS AND DISCUSSION

Thermal indices

Bud burst of all the three cultivars took place on 1st February during the year 2013 and on 30th January during the year 2014. 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 Kala Amritsari followed by Satluj Purple and Titron. Similar trend was observed in photothermal units (PTU), heliothermal units (HTU) and hydrothermal unit (HYTU).

After completion of dormancy and beginning of bud burst Kala Amritsari required absolute value of 35 GDD, 186 PTU, 375 HTU and 2876 HYTU, Satluj Purple required 48 GDD, 234 PTU, 519 HTU and 3953 HYTU and Titron required 56 GDD, 268 PTU, 606 HTU and 4645 HYTU, respectively. Similar trend was observed in heat indices for next phenophases like white, full bloom, petal fall and physiological maturity (Table 1). Kala Amritsari required less numbers of growing degree days for attaining different phenophases followed by Satluj Purple and Titron cultivar.

The mean of two years of thermal indices by Kala Amritsari from break of dormancy to attain physiological maturity were 965 GDD, 7863 PTU, 11904 HTU and 58897 HYTU by Satluj purple 986 GDD, 8051 PTU, 12172 HTU and 59578 HYTU and by Titron 1146 GDD, 9570 PTU, 14332 HTU and 65876 HYTU (Table 1). The growth period during the year 2014 was almost one week longer as compared to the year 2013, which might be due to the cloud weather and more rains received from fruit set to maturity during the year 2014. Days taken to attain different phenophases by Kala Amritsari and Satluj purple were almost at par but Titron has taken 3-12 days more for attaining different growth stages in plum. From dormancy to bud burst the average days taken by Kala Amritsari was 11days, Satluj Purple 14 days and Titron 15 day and total days taken to attain

Table 1 : Thermal unit and PTI used for attaining different phenophases (Pooled data).

	Days Taken	GDD (^{0}Cday)	PTU(^{0}Cdayhour)	HTU(^{0}Cdayhour)	HYTU(^{0}Cday%)	PTI(^{0}C)
Kala Amritsari						
Bud burst	11	35.2	186.0	375.0	2876.1	3.2
White bud	17	35.0	155.3	380.1	2857.3	4.0
Full bloom	30	48.1	283.6	534.2	3837.6	3.9
Fruit set	38	41.3	266.3	470.3	3438.5	4.2
Maturity	101	805.7	6971.9	10144.7	45887.8	9.6
Satluj Purple						
Bud burst	14	48.5	234.3	519.4	3953.4	2.9
White bud	21	35.4	190.3	385.5	2910.7	3.9
Full bloom	32	45.8	278.8	511.8	3612.5	4.0
Fruit set	40	40.5	283.0	462.8	3262.2	4.3
Maturity	107	815.8	7065.0	10292.9	45839.2	9.2
Titron						
Bud burst	15	56.6	268.3	606.6	4645.5	3.8
White bud	25	37.6	225.7	412.6	3010.1	3.8
Full bloom	35	50.1	279.6	564.5	4082.3	4.1
Fruit set	43	44.5	363.4	513.0	3344.9	4.4
Maturity	113	957.0	8433.2	12234.9	50793.3	10.1

Table 2 : Thermal use efficiencies of three genotypes of plum at Hisar conditions

Cultivars	**HUE** (kg ha^{-1} degree day)	**HTUE** (kg ha^{-1} degree day)	**PTUE** (kg ha^{-1} degree day)	**HYTUE** (kg ha^{-1} degree day)
Kala Amritsari	21.5	2.6	1.7	0.4
Satluj Purple	18.3	2.2	1.5	0.3
Titron	13.7	1.6	1.1	0.2

maturity were 101 for Kala Amritsari, 107 for Satluj Purple and 113 for Titron, respectively (Table 1).

Phenothermal index (PTI)

Phenothermal index steadily increased from bud burst stage to maturity in all the cultivars. It was highest from petal fall to maturity stage, which is the longest stage and during this period (March - April) the accumulation of heat units were higher. The value of the PTI was lowest in Satluj Purple followed by Kala Amritsari and Titron for different phenophases. On an average of the PTI was 2.9, 3.9, 4.0, 4.3, and 9.2 for bud burst, white bud, full bloom, petal fall and physiological maturity, respectively in Satluj Purple. The corresponding values of PTI for Kala Amritsari were 3.2, 4.0, 3.9, 4.2, and 9.6, and for Titron it were 3.8, 3.8, 4.1, 4.4 and 10.1 for bud burst, white bud, full bloom, petal fall and physiological maturity, respectively (Table 1).

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 plum the highest use efficiency (21.5 kg ha^{-1} GDD^{-1}) was observed in cultivar of Kala Amritsari followed by Satluj Purple (18.3 kg ha^{-1} GDD^{-1}) and the lowest heat use efficiency (13.7 kg ha^{-1} GDD^{-1}) was observed in Titron (Table 2). The utilization efficiency for other indices also followed similar trend. On an average of the thermal use efficiency in Kala Amritsari was 12.4 kg ha^{-1} GDD^{-1} with 28

per cent of coefficient of variation. In Satluj purple it was 10.7 kg ha^{-1} GDD^{-1} with 33 per cent of coefficient of variation and in Titron the average heat unit use efficiency was observed 8.7 kg ha^{-1} GDD^{-1} per cent with 37 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 and 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 required equation for forecast of fruit yield is as under:

(1) *For Kala Amritsari:* $FY = 4341\ HU - 203.6$ ($R^2 = 0.94$)

(2) *For Satluj Purple:* $FY = 0.3122\ HU - 152.8$ ($R^2 = 0.88$)

(3) *For Titron:* $FY = 4833\ HU - 420.6$ ($R^2 = 0.84$)

(4) *For Pooled data:* $FY = -0.186\ HU + 377.7$ ($R^2 = 0.71$)

The Kala Amritsari and Satluj purple showed higher thermal use efficiencies and also showed a better relation in comparison with Titron and the pooled model.

Thermal indices explained 94 percent variation in fruit yield of Kala Amritsari, 87 per cent variation in Satluj purple and 83 percent variation in Titron. 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.

CONCLUSIONS

The thermal indices were found to vary significantly among the 3 cultivar of plum. The performance of Kala Amritsari was observed better followed by Satluj Purple in term of plant growth, plant girth, annual extension, fruit set and other physical parameters. They showed better utilization of heat units and hence, suitable for diversification in plum cultivation under changing and prevailing climatic conditions of Gigantic plain in general and semi arid region of Haryana in particular.

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Received : January 2015 ; Accepted : August 2015