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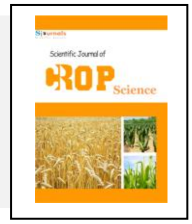

Original article

Safflower growing degree days in different temperature regimes

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The plant growth and development are affected by many environmental factors, but the air temperature is the most effective one. During growing season plants accumulate growing degree days (GDD) or heat unit to complete a growth stage. Therefore, the GDD or HU is more accurate for prediction of developmental stages than number of days for different environmental and planting date. A field experiment was conducted in 2007-2008 at Kabotarabad Agricultural Research Station of Isfahan. Eight planting dates (March 5, March 20, April 3, April 18, May 4, May 19, June 5, and June 22) and three safflower cultivars (Arak, Sofea and Goldasht) were evaluated, using a randomized complete block design with split- plot layout in six replications. Dates of planting were considered as the main plot and cultivars were randomized in the sub-plots. Date of planting significantly affected number of days and GDD of developmental stages and seed yield. Delay in planting until seven planting date reduced seed yield and length of planting to emergence, emergence to head visible, emergence to flowering, emergence to ripening, planting to ripening and seed yield. These traits increased a little in eight planting date but GDD of these stages did not show any specific trend. Cultivars significantly affected developmental stages duration and related GDD. Sofeh and Goldasht were the latest and earliest cultivars, respectively. There was no significant difference among seed yield of cultivars.

1. Introduction

Although different environmental factors influence plant growth, but air temperature is one of the basis and most important factor which influence plant growth and development (Hajehpour, 1377; Mozafari, 1384; Delavega and Hall, 2002). One of the practical applications of temperature on plant growth in agricultural field is heat unit or growing degree days (GDD) which is used for estimation of plant growth and development periods. Using GDD is based on the fact that plants require specific amount of heat units for growth and developmental stages (Mozafari, 2001; Gilmore and Rogers, 1985). Therefore, using GDD for prediction the plant growth and developmental stages is prefer to time unit (days) in different location due to variation of climatological situation in different regions. The relation of different plant developmental stages with accumulation of GDD and indifferences to time unit were first recognized in 1735 (Gilmore and. Rogers, 1985) and nowadays most plant scientist take advantage of it for determination of different plant growth stages.

Safflower (Carthamus tinctorius L.) is an annual oil plants, with wide leaves from composite family, and is highly tolerance to salinity and drought stresses (Rohini and Sankora, 2000). Safflower historically is cultivated for colure extraction from the petals in cloth dying and food decoration (Cho and Tae, 1995), and it's cultivation as an oil crop is not very old, therefore is called a new oil crop. The meal is used as animal feed and the seeds are sold for birdseed. In Iran, the safflower cultivated area is about 6 thousand hectares, and average seed yield of 1 ton/hectare. The highest cultivated area is located in Isfahan, Khorasan, and Yazd provinces (Froozan, 2005).

In Esfahan Province safflower is cultivated in marginal land and face with salinity and drought stress during growing season. Therefore, prediction of the sensitive yield formation and growth stage is requiring for decrease such limiting conditions. Study and predicting different vegetative and reproductive developmental stages with respect to time (phenology) is vital strategy to alleviate plant stresses, during sensitive developmental stage.

In additional to environmental factors, timing of different phenological stages depends on safflower cultivars and the genotype plays an important role in timing of each developmental stage (Dadashi and Khajehpour, 2004; Yasari et al., 1995). In the study of four cultivars and one line of spring safflower the effects of genotype on number of days to accumulated GDD were significant for all developmental stages. The Zarghan 279, and Zhiela cultivar with 2041 and 2820 GDD were the earliest and latest cultivars, respectively (Bagheri, 1994). In another study among different safflower cultivars the Nederdest with 117 growing days and 1594 GDD, and Arak Cultivar with 129 growing days and 1820 GDD were the earliest and latest genotypes, respectively (Nejadshamlo, 1986). In Khorasan Province three: low, medium and high yielding safflower cultivars showed significantly different developmental period duration (Zand, 1986). In India for 100 lines of safflower, the correlation coefficient between seed yield and 75% maturity stage was positive and significant (Pandya, et. al., 1996.). Yasari et al., (1384) studied the developmental stages of 10 advanced safflowers and find branching duration is the most sensitive stage of yield and yield components.

The objective of the present study is to use GDD to investigate the developmental stages of safflower in different planting dates.

2. Materials and methods

This study was conducted in 2007-2008 growth season in Kabotarabad agricultural research station. This station (32’ 30 N, and 51 49 East L, and 1541 masl) is located at 30 Km south-east of Isfahan city. According to Kopen climate classification is located in a dry, very hot, with hot and dry summer. The long time mean annual precipitation of 212 mm and temperature of 16.1 Celsius degree. In this experiment three safflower cultivars namely: Arak (Spin, yellow flower, tall), Sofea (spineless, red flower, tall) and Goldasht (spineless, red flower, tall) were compared on eight planting date of first (5th March), second (20th March); third (3th April), forth (18th April), fifth (4th May), sixth (16th May), seventh (5th June) and eighth (22th June). The experimental design was a randomized complete blocks and replicated six times with split plot arrangement of planting date and cultivars in the main and sub-plots, respectively. The plot consisted of 4 rows in which the first and forth rows and half a meter length from end of each rows were elimination and the reaming plants were constitute the sampling population. Commercial cultural practices were employed during growing season.

Plant developmental stages for each plot was evaluated according to following schemes: a) the plant emergence, when the 90 percent cotyledon emerge in planted row, b) heading, when on 10% of plant, head with 1 cm in diameter at the end of main stem become visible C) Flowering, the beginning of flower pollination in the main stem, in 10% of plant, D) Ripening, when 90% of heading turn into brownish colure. The number of days for each developmental stage from sowing to emergence, emergence to heading (1 cm in diameter), emergence to flowering, emergence to ripening, and sowing date to maturity was recorded. For counting the days and calculation of GDD the first day of each stages were and last days of each stage were not, include in the growth period.

The weather data during the growth season from the Kabotarabad agricultural synoptic weather station were used to calculate the GDD. The daily heat unit based on GDD was calculated according to Hi= (Tmin+ Tmax)/2-Tb and the summations were calculated for each developmental stage. Where Hi is the growing degree days, Tmin and Tmax are the minimum and maximum daily air temperature, respectively. Tb is the base temperature and is equal to 5 degree Celsius (Yasari et al., 1995).

The yield was determined from the two middle rows of 2.4 m2 based on 13 percent moisture content. The seed moisture content was determined by placing the seed in a ventilated oven for 24 hours at 65 degree Celsius. The data was subjected to analyses of variance and the means were compared by Duncan multiple range test method based on 5 percent probability level.

3. Results and discussions

The day length, the daily minimum, maximum and mean air temperate during 2007-2008 growing season is shown in figure 1. The day length at the beginning of the experiment in March is 11.91 hours and by the end of growing season in October is 11.89 hours. The highest daylenght of 14.56 hours was in July. The mean air temperature during the growing season in March, April, May, June and July uniformly increased, and during Aug., Sept. and Oct. decreased slowly.

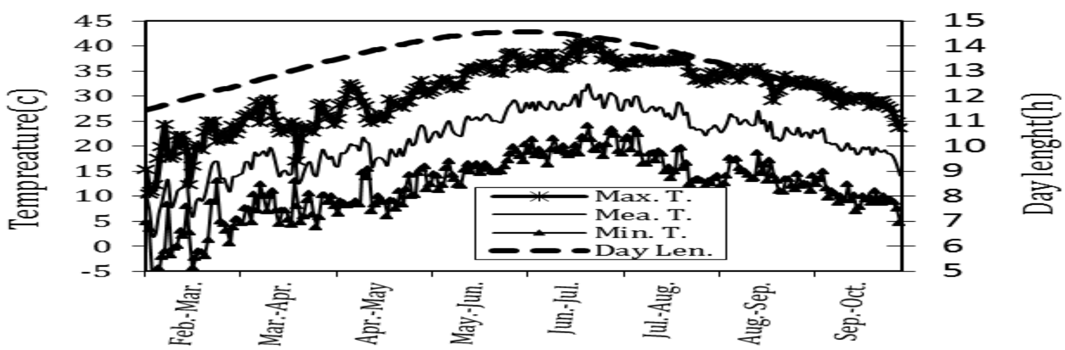

Fig. 1. The course of day length, minimum, maximum and mean air temperature for 2007-2008 growing season.

The effect of planting date on day from days of planting to emergence and cumulative growing degree days (GGD) were significant at 1 percent probability level (table 1). By delaying planting date up to eighth planting date (22th June) the number of days and corresponding GDD's decreased (table 2). Even though the seed germinate in the soil but the soil upper surface temperature in the planting depth is in harmony with air temperature but the relation between air temperature and soil temperature is not simple and the soil upper surface temperature is affected by soil colure, texture, moisture, cover, and slope rate ant its direction(Mozafari, 1996). Therefore, direct measurement of upper soil temperature for estimation of sowing to seed emergence is required but this measurement because of required specific instrument in common farm is difficult.

The effect of planting date on number of days and GDD's from germination to heading, germination to flowering, germination to maturity and planting to maturity were significant at 1 percent probability level (table 1). Generally, postponing planting date up to 7the planting date, the corresponding number of days and GDD's decreases for while they slightly increase for the 8th planting date(table 2). The significant effect of planting dates on the decreasing number of days to different development stages is due to warming of air temperature with postponing sowing date, and is reported by others (Dadashi and Khjehpour, 2004, Delavega and Hall, 2002 and Emami et al., 2011). The significant effect of planting date on GDD is not expected due to assumption of invariability of GDD for and developmental stages, in different location and thermal regimes, and generally the different planting date should not show any significant effect. The lack of such responses may be due to pressure of temperature effects in later planting date and none linearity of developmental rate to air temperature in the given range.

The numbers of days and GDD's from flowering to maturity were significantly affected by planting dates (table 1) but no trend was observed in number of days and GDD's with planting dates. The minimum and maximum days and GDD's from flowering to maturity resulted from 8th and 4th planting date, respectively. Such results may be due to short period of flowering to maturity stage and effect of late season irrigation application on maturity.

The effect of planting date on seed yield was significant. The seed yield trend from first to 8th planting date was similar to number of days and GDD's from plant emergence to maturity, and planting date to maturity. The seed yield decreased from first to 7th planting date, and then slightly increased in 8th planting date table 2). Generally by delaying in planting date, seed yield of cultivars decreased. Due to increasing temperature with delaying planting date, the required thermal heat unit (GDD) of cultivars is satisfy in a shorter period and plants are facing with increasing temperature stress and hasten development. Lowering of growth period, diminishing plant photosynthesis' capacity, early flowering and coincident of plant yield formation period with high temperature leads to yield decreases (Yasari et al. 1995, Delavega and Hall, 2002 and Emami et al., 2011, Mundel et al., 1994, Nickabadi et al., 2008 and Omidi 2010).

The effect of cultivars on number of days from planting to emergence and the corresponding GDD were not significant, but its effects on other measured phonological traits were significant (table 1). Except flowering to maturity developmental stage in which the Soffea cultivar had the minimum number of days and corresponding GDD's from planting to emergence for the rest of phonological stages the Soffea and Goldasht had the minimum and maximum values, respectively (table 2). Different length of growing stage has been reported for different safflower cultivars ((Dadashi and Khjehpour, 2004 3; Shahsavari et al., 2012 ; Yasari et al. 1995).

The effect of cultivars on seed yield was not significant (table 1). Soffea and Goldasht cultivars produced the minimum and maximum seed yield (1921 and 1829 kg ha-1), respectively. The Arak cultivar seed yield of 1893 kg/ha were between minimum and maximum ones (table 2).

The interaction effect of planting date×cultivars were significant on number of days form emergence to flowering, planting and emergence to maturity, and flowering to maturity, and GDD from flowering to maturity, emergence to maturity and planting to maturity (table 1), which shows the different response of defined cultivars to different planting dates for these traits.

The cluster analysis of 8 planting date with 13 studied traits is given in figure No. 2. In scale of about 25 the 6th to 8th planting date are separate from the rest. In scale of about 10, the 5th planting date is separated from first to 4th planting dates and in scale of about 3 the 6th planting date are separated from 7th and 8th planting date. Finally in scale of 0 all planting date are separated from each others. Therefore it is concluded that the early planting dates is located in one group; and late planting dates in another group.

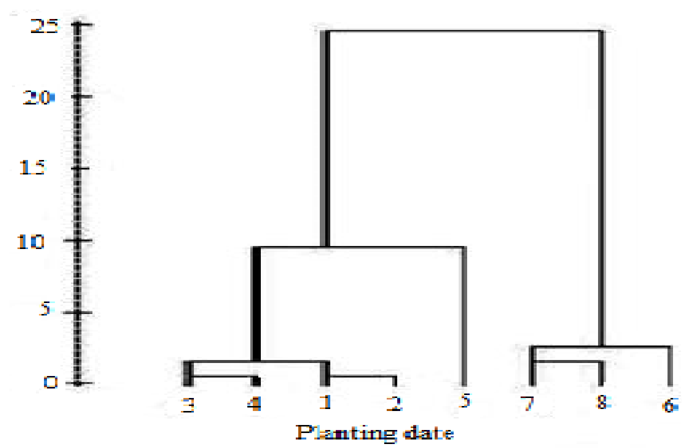

Fig2.Safflower planting date denderogram

Table 1
Analysis of variance of days (DAS) and cumulative growing degree days (GDD) for different developmental stages and seed yield at different planting dates for 2007-2008 growing season.

SOV	d.f	Planting to emergence		Emergence to heading		Emergence to flowering		Flowering to maturity		Emergence to maturity		Planting to maturity		Yield
		DAS	GDD	DAS	GDD	DAS	GDD	DAS	GDD	DAS	GDD	DAS	GDD	
Replication.	5	0.97**	445**	55**	30185**	4*	78222*	35**	29040**	73**	54036**	146**	52928**	1073172**
Planting date (A)	7	323.22*	64821**	1761**	534545**	2378**	707136**	381**	241501**	2361**	935235**	4200**	1197742**	14050147**
Error a	35	0.62	528	26	16508	4	5140	13	11858	88	13219	24	12753	325791
Cultivar (B)	2	1.08*	278**	177**	147555*	175**	35100	38**	18989**	2693**	975586**	215**	88216**	107474
A*B	14	0.50	75	5	8867	4**	5218	7**	4744*	141*	7237**	11**	4653**	160578
Error b	80	0.34	195	3	8093	2	9371	2	1580	71	1355	9	1223	90468

* and ** significant at 5 and 1 percent probability level, respectively .

Table2
Mean comparison of the number of days (DAS) and cumulative degree days (GDD) for different developmental stages and seed yield at different planting dates.

Experimental factors	Planting to emergence		Emergence to heading		Emergence to flowering		Flowering to maturity		Emergence to maturity		Planting to maturity		Yield (Kg/ha)
	DAS	GDD	DAS	GDD	DAS	GDD	DAS	GDD	DAS	GDD	DAS	GDD	
Planting date													
5-March-08	17.2^{a}	280^{a}	58.5^{a}	1242^{a}	78.9^{a}	1743^{a}	31.4^{b}	783^{b}	110.6^{a}	2662^{a}	127.5^{a}	2851^{a}	3304^{a}
20-March-08	13.3^{b}	274^{a}	55.2^{a}	1212^{a}	74.7^{b}	1665^{b}	29.6^{bc}	739^{bcd}	108.7^{a}	2527^{b}	117.6^{b}	2708^{b}	3029^{a}
3-April-08	12^{c}	221^{a}	49.7^{b}	1168^{a}	66.4^{c}	1550^{c}	27.4^{cd}	683^{cde}	97.7^{b}	2332^{c}	105.7^{c}	2480^{c}	2193^{b}
18-April-08	9.6^{d}	213^{b}	44.6^{c}	1074^{b}	60.1^{d}	1438^{d}	25.1^{d}	639^{cde}	88.4^{cd}	2167^{d}	95.1^{d}	2308^{d}	1794^{c}
4- May-08	8.3^{c}	208^{b}	43.8^{c}	1071^{b}	55.7^{c}	1368^{c}	27.8^{cd}	675^{dc}	85.2^{dc}	2113^{dc}	90^{e}	2216^{c}	1013^{d}
19- May-08	7.2^{f}	157^{c}	32.9^{d}	811^{c}	49.8^{g}	1235^{f}	29.9b^{c}	743^{bcd}	81.9^{dc}	2054^{c}	87.4^{ef}	2193^{ef}	1175^{d}
5- June-08	5.1^{g}	128^{d}	36.1^{d}	900^{c}	49.2^{g}	1225^{f}	30.4^{b}	760^{bcd}	81.4^{cd}	2036^{c}	84.9^{f}	2123^{f}	1183^{d}
22-June-08	5^{g}	125^{d}	32.9^{d}	822^{c}	51.4^{f}	1275^{f}	40.5^{a}	1015^{a}	93.5^{b}	2334^{c}	95.1^{d}	2418^{d}	1355^{d}
Cultivar													
Soffea	9.7^{a}	201^{a}	46.3^{a}	1095^{a}	63^{a}	1446^{ab}	29.4^{c}	734^{b}	101.6^{a}	2438^{a}	101.3^{a}	2438^{a}	1921^{a}
Arak	9.9^{a}	203^{a}	43.4^{b}	1032^{b}	41^{b}	1456^{a}	31.2^{a}	773^{a}	97.1^{b}	2232^{b}	101.6^{a}	2435^{a}	1893^{a}
Goldasht	9.6^{a}	198^{a}	42.7^{b}	985^{c}	59^{c}	1407^{b}	30.2^{b}	757^{a}	86.9^{c}	2164^{c}	97.9^{b}	2363^{b}	1829^{a}

Means within columns followed by the same letter are not significantly different bases on Duncan multiple range test (P<0.05).

The Pearson correlation coefficient between measured responses is given in table 3. A positive and significant correlation between number of days and GDD is observed for each developmental stage. Except for flowering to maturity, the number of days and GDD of all other developmental stages were positive and significant at 1 percent probability level. The seed yield correlation coefficient with all traits except number of days from flowering to maturity and corresponding GDD were positive and significant at 1 percent probability level. Number of days from planting to maturity show the highest correlation (r=0.98**) with seed yield. In accordance with calculated correlation coefficient number of days from planting to maturity were the only variable which entered the regression model and explained 95.4 percent of seed yield variation (table 4).

This study shows the acceleration of plant developmental stages with delaying planting dates up to June, 5th. The resulting show significant difference between cumulative GDD for any defined given developmental stage in different planting dates and between cultivars in different developmental stages and cumulative GDD.

Table 3

The Pearson correlation coefficient between various characteristic of safflower in different planting dates for 2007 to 2008 growing seasons.

		1	2	3	4	5	6	7	8	9	10	11	12
1	Days from Planting to	1											
2	GDD from Planting to	0.95	1										
3	Days from emergence to capitulum	0.91	0.82	1									
4	GDD from emergence to capitulum	0.85	0.76	0.98	1								
5	Days from emergence to flowering	0.95	0.88	0.97	0.92	1							
6	GDD from emergence to flowering	0.95	0.87	0.98	0.94	0.99	1						
7	GDD from emergence to maturity	0.84	0.86	0.84	0.76	0.93	0.92	1					
8	GDD from emergence to	0.81	0.77	0.79	0.69	0.89	0.88	0.99	1				
9	Days from planting to maturity	0.92	0.83	0.89	0.81	0.97	0.96	0.98	0.97	1			
10	GDD from planting to maturity	0.86	0.77	0.93	0.83	0.93	0.91	0.99	0.99	0.99	1		
11	Days from flowing to Maturity	-0.31	-0.39	-0.38	-0.48	-0.22	-0.25	0.13	0.23	0.01	0.15	1	
12	GDD from flowing to Maturity	-0.3	-0.38	-0.38	-0.48	-0.21	-0.24	0.14	70.24	0.07	0.16	0.99	1
13	Grain yield	0.93	0.88	0.90	0.81	0.97	0.95	0.95	0.92	0.98	0.95	-0.09	-0.07

Table 4
The summary of step wise regression for estimation of safflower yield in different planting dates.

Variable	R2	Partial R2	R2 Significant level	Regression coefficient	Standard error of regression	Regression coefficient Significant level
Intercept	--	--	--	-3785.44	513.0	0.0003
Number of days to maturity	0.954	0.954	0.0001	56.42	5.06	0.0001

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