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PHENOPHASIC HEAT UNITS REQUIREMENT AND GROWTH VARIATIONS OF SAFFLOWER VARIETIES UNDER DIFFERENT SOWING DATES

S.V. Khadtare[1], S.K. Shinde [2] and L. N. Tagad [3]

ABSTRACT

The field experiment was conducted at the dry farming research station, Solapur during post rainy season of 2012-13 and 2013-14. The experiment was composed of three different sowing dates and seven varieties of safflower. Early sown safflower requires 7-9 days more for attaining physiological maturity than latest sown safflower. Among the varieties, SSF – 708 was found significantly more efficient over other genotypes in duration and yield. The deviation in heat unit requirement among early and late sown safflower due to sowing dates was <100° C. An early sown safflower completed the life cycle by obtaining 1684°C thermal units. Variety SSF-708 attained physiological maturity at 1492°C and NARI -57 the late maturing variety attended physiological maturity at 1628°C heat units. Similar trend was noticed in helio and photothermal units requirement of safflower. An increasing trend in leaf area upto 50 per cent flowering and gravitating trend towards the physiological maturity was noticed over sowing dates. Higher dry matter (DMP) was noticed under crop sown during first and second fortnight of September. At the end of physiological maturity, SSF-748 found better (94.32 g pl^{-1}) and SSF-708 (91.44 g pl^{-1}) was second in order for dry matter production.

(Key words: Dry matter, GDD, HTU, PTU, LAI)

INTRODUCTION

Safflower (*Carthamus tinctorius* L.) is an annual, broad leaf oilseed crop of the family compositae adapted chiefly to dryland or irrigated cropping systems. Safflower was originally grown for the flowers that were used in making red and yellow dyes for clothing and food preparation. With earlier maturity, crop development of winter safflower would occur when temperatures are lower and moisture more plentiful than spring sown safflower. India ranks first in the world with an area of 1.78 m hectares accounting for 47% area and with a production of 1.14 m tones accounting for 27 per cent of world's production in 2014. Maharashtra is the largest producer of Safflower having 63% (61 m tonnes) production from the largest growing area of 67% (107 m ha).

The productivity of the crop showed impressive advance increasing from just 203 kg ha^{-1} during 1962-63 to 641 kg ha^{-1} during 2013-14 (Anonymous, 2015).

Safflower can perform well under various climatic and soil conditions. Temperature variations in the field can be treated by sowing crops at different dates in the season. Temperature is a major environmental factor that determines the rate of plant growth and development. In addition, it's resistant to some diseases and susceptible to humidity. The rate of plant development is mainly temperature and photoperiod driven (Ritche and Nesmith, 1991). Regarding growth conditions, safflower is not selective and is more tolerant to drought and low temperatures (*e.g.* -12 °C) than other oilseed crops. It was reported that the sowing date of safflower vary depending on ecological conditions (Ozel *et al*., 2004). Winter crops are vulnerable to high temperature during reproductive stages and differential response of temperature change (rise) to various crops has been noticed under different production environments (Kalra, 2008). Documented increases in global temperatures have stimulated interest on the direct effects of temperature and other climatic variables on plant growth, yield and quality of oil crops. The genotypes exhibit different response under same as well as in different environmental conditions (Allard and Bradshaw, 1964).

Growing degree days (GDD) and helio-thermal units (HTU) are a measure of heat accumulation and used by agricultural scientists to predict crop development rates (Yasari *et al.*, 2014). Though accumulation of growing degree days and photothermal units (PTU) for each developmental stage is relatively constant and independent of sowing date, crop variety may modify it considerably (Phadnawis and Saini, 1992). Having wider adaptability, different safflower genotypes require different total number of cumulative degree days or heat units for growth, development and maturity. The crop heat unit (CHU) system suggests that the temperature response of development differs between the day and the night. Sowing date is among the predictable and major non monetary agronomic factor influencing leaf area and dry matter production in safflower. Hence, a field

1. Asstt. Professor, AICRP on Safflower, Krishak Bhawan, ZARS, P.O. Box-207, Solapur 413 002 (India)
3. Jr. Breeder, AICRP on Safflower, Krishak Bhawan, ZARS, P.O. Box-207, Solapur 413 002 (India)

investigation was carried at AICRP, Safflower, Solapur for two consecutive years (2012-13 and 2013-14) to know the phase-wise heat unit requirement and to find to determine its effect on leaf area and dry matter production of safflower.

MATERIALS AND METHODS

The field experiment was conducted in post rainy season for two years at dry farming research station, Solapur during 2012-13 and 2013-14. The centre comes under scarcity zone and geographically situated at 17º 41´ North latitude and 75º 56´ East longitude at 483.6 meter above mean sea level (MSL). The rainfall of this region is characterized by inadequate, ill distributed and erratic nature. The annual normal rainfall is 723.4 mm in 40 to 45 rainy days while, the *rabi* normal is 237.8 mm (Anonymous, 2015). Normal maximum temperature and minimum temperature were in the range of 29.8 to 34.5 and 13.3 to 21.8°C, respectively and number of bright sunshine hours and hours of photoperiod were in the range of 0.8-10.1 hr and 11.3- 12.2 hrs respectively during the crop growth period for both the years. The experiment composed of three sowing windows *i.e* first fortnight of September, second fortnight of September and first fortnight of October. Seven different varieties of safflower were used for the study. The experiment was laid out in split plot design and replicated four times. The crop was fertilized with the recommended dose of fertilizers (50:25: 0 kg NPK ha^{-1}) through urea and single super phosphate at the time of sowing by band placement. Safflower seeds were hand dibbled at 45 cm x 20 cm spacing. All the agronomic practices were followed to maintain the crop condition satisfactory. The observations were recorded at the end of each physiological growth stages . Meteorological data was obtained from the agrometeorological observatory of DFRS, Solapur. Daily maximum, minimum, mean temperature, number of bright sunshine hours and photoperiod during the study of 2012-13 and 2014-15 were taken into consideration for phase wise calculation of GDD, HTU and PTU. The base temperature used for growing degree days (GDD) computations was 10°C. Thermal response of sowing dates can be quantified by using the heat unit or thermal time concept and calculated according to the equation,

$$GDD = \sum_{i=1}^{n} \frac{Timax + Timin}{2} - Tb$$

Where, Timax = Daily maximum temperature of day i (°C), Timin = Daily minimum temprature of day i (°C), Tb = Base temperature of safflower and, heliothermal units were calculated by the formula given by Ritchie and Nesmith, (1991). HTU = Bright sunshine hours x GDD

The photo-thermal units were calculated by following formula as given by Wilsie (1962). PTU= Day length X GDD. The leaf area in present investigation was determined by direct method using leaf area meter of LAI - 3050C canopy analyser (Li-COR, Inc., Lincoln, NE). The leaves were detached from the uprooted plant and then the leaf area was measured in cm^2. The leaf area index was calculated by using formula,

LAI= Leaf area (cm^2)/ Ground area (cm^2)

For determining stage wise dry matter plant^{-1}, uprooted plant from each plot was washed and was sun dried and then allowed drying in thermostatically controlled hot air oven at 60 ± 2°C till constant weight was recorded. The dry matter study was carried out at the end of each growth stage.

RESULTS AND DISCUSSION

Temperature is the key factor that influences plant growth and development. Data perusal to growing degree days, heat units and photothermal units required to complete the phenological growth stages are furnished in table 1 to 3. Data exhibited that, numerically higher cumulative degree days required to attain the physiological maturity were reported under early sown safflower (1684°C). Whereas, midlate sown safflower attended the physiological maturity on cumulative accumulation of degree days of 1596 °C (88°C > D_1). Higher cumulative GDD requirement under early and midlate sown safflower was attributed to increased degree days (496°C) between rosette termination and flower initiation stages under D_1 and between germination and rosette termination (452°C) stages under midlate sown safflower. This variation in GDD among the different stages might be due to the variation in temperature prevailed during these phenological growth stages. Arslan *et al.* (1997) reported that high temperatures at germination and subsequent stages resulted in early completion of physiological maturity. The accumulation of HTU is a bright sunshine hour (BSS) driven phenomena in the life cycle of a crop (Reda *et al*., 2013). The data in table 2 showed the differences in stage wise HTU requirement of safflower. The midlate sown safflower (D_2: SF Sept) accumulated maximum HTU (14667°C) and early sown safflower (D_1) was second in order (14427). The safflower sown during first fortnight of October was matured on accumulation of 14069°C HTU. Variation in accumulation of HTU could be attributed to the bright sunshine hours (BSS) during different growth phases. In case of early sowing (D_1), less number of BSS was observed during germination and upto the end of rosette termination than midlate sown safflower (D_2).

Data on photothermal units (PTU) requirement are given in table 3. The PTU for a day represents the product of GDD and the possible sunshine hours as the day length (Thavaprakash *et al*., 2007). It was found that in general a progressive delay in sowing causes a decrease in PTU requirement of constituent phenophases as well as for the crop duration. So, the safflower sown during first fortnight of September showed higher PTU requirement over midlate (D_2) and late (D_3) sown safflower. The results are also noticed by Pal *et al*. (2013) wherein, early sown crop experienced the temperature and higher number of photoperiod day^{-1} than late sown crops.

The GDD, HTU and PTU are good estimators of safflower growth stages. Though accumulation of photo thermal units for each developmental stage is relatively constant and independent of sowing date, crop variety may modify it considerably (Phadnawis and Saini, 1992). The data revealed visible differences among the genotypes for the degree days and heat unit requirements. Among different varieties under investigation, A-1, Phule Kusuma, SSF-748, PBNS-12 and NARI-6 had completed the phenological growth stage on receiving the cumulative GDD between the range of 1545 and 1588^{o}C. Variety NARI-57 required numerically higher degree days (1628^{o}C). Significantly lower leaf area of Var. NARI -57 lead to lesser water loss through evapo-transpiration. The increased soil moisture availability period might be the reason of duration stretched during germination to rosette termination (472^{o}C). While, variety SSF 708 found most efficient in case of calories requirement (1492^{o}C). Reda *et al.* (2013) reported the positive correlation (r=0.97) between accumulation of GDD and soil moisture availability at different growth stages and maturity of crop. Var. SSF -708 has completed each growth stage on receiving decreased growing degree days. This implies an earliness of a genotype SSF-708. Highest heliothermal and photothermal units required under NARI -6 (14932 and 19325, respectively) and lowest were reported under SSF- 708 (13689 and 17699, respectively).

Data on leaf area and leaf area index (LAI) recorded at the end of each growth stages are presented in table 4. An increasing trend in leaf area upto 50 per cent flowering and gravitating trend towards physiological maturity was noticed over the sowing dates. Data further revealed that, crop planted during first and second fortnight exhibited at par leaf area upto flower initiation and D_1 at 50 per cent flowering resulted in significantly superior over rest of the sowing. A drastic reduction in LA at physiological maturity was attributed to leaf drop due to senescence. Among the different varieties under consideration, SSF-748 found significantly superior in leaf area and LAI at the end of all the growth stages. Second in order was PBNS -12 at the end of rosette termination while flower initiation onwards SSF - 748 was closely followed by SSF -708. Significantly lowest leaf area and index was observed under NARI -57. Varieties SSF 748 and SSF 708 might be tolerant to prevailing high temperature and well developed root system of these two varieties allowed the better and expanded photosynthetic apparatus over the crop growth period. Recent research indicated that LA rate of water loss from excised leaves are drought independent criteria and controlled genetically. However, the soil moisture availability duration had the significant role under stressed condition. (Ashkani *et al.,* 2007).

Data perusal to stage wise dry matter production (g plant^{-1}) of different safflower genotypes sown at three different sowing windows are given in table 6. Data showed the significant changes in dry matter production (DMP) plant^{-1} from rosette termination stage onwards. Higher DMP was noticed under crop sown during first fortnight of September (D_1) and it was closely followed by D_2 sown crop upto flower initiation. The respective DMP values under D_1 and D_2 were 3.06 and 2.83, respectively at the end of rosette termination and 69.92 and 62.83, respectively at the flower initiation. At 50 per cent flowering and physiological maturity, highest values of DMP were noticed under crop sown at D_1 alone. Crop physiological process dependent on integrated atmospheric parameters. Under desired conditions of D_1 sowing, a desirable vegetative period and dry matter was increased significantly during formation of reproductive organs.

Late planting date (D_3) in addition to reducing vegetative growth, dry matter production also decreased due to undesired environmental conditions and lack of suitable transforming presented matter other plant parts, as a results of increasing temperature at the end of each growth stage (Emami *et al.*, 2011).

Dry matter yield was significantly influenced ($p < 0.05$) with different genotypes under investigation. Data showed the differential response of varieties with prevailed weather condition during the growth stages. At rosette termination, PBNS-12 (3.46 g pl^{-1}) was significantly higher and was at par with NARI- 57 (3.22 g pl^{-1}) and SSF -708 (3.15 g pl^{-1}). From flower initiation onwards, *cv.*SSF-748 produced significantly higher dry matter. At the end of physiological maturity stage, SSF-748 found better (94.32 g pl^{-1}) and SSF-708 (91.44 g pl^{-1}) was remaining second in order.

Table 1. Stage -wise heat unit requirement of safflower- growing degree days (°C)

Treatments	Phenological growth stage					
	Sowing – Germination	Germi.– Rosette	Rosette – Bud Ini.	Bud ini– 50 % flowering	50 % flower– P.mat.	Total
Sowing dates						
D_1:FF Sept.	88	431	496	171	498	1684
D_2:SF Sept.	81	452	441	168	454	1596
D_3:FF Oct.	83	418	386	137	399	1423
Varieties						
Annigeri-1	82	432	443	163	451	1571
SSF-708	82	410	424	144	432	1492
P.Kusuma	87	437	452	151	459	1586
SSF- 748	82	427	437	159	440	1545
PBNS-12	87	416	439	161	459	1562
NARI-57	87	472	442	170	457	1628
NARI-6	82	442	449	166	449	1588

Table 2. Stagewise heliothermal units (°C) requirement of safflower

Treatments	Phenological growth stage					
	Sowing – Germination	Germi.– Rosette	Rosette – Bud Ini.	Bud ini — 50 % flowering	50 % flower- P.mat.	Total
Sowing dates						
D_1:FF Sept.	625	3491	4122	1558	4631	14427
D_2:SF Sept.	640	3887	3925	1630	4585	14667
D_3:FF Oct.	689	3929	3744	1397	4309	14069
Varieties						
Annigeri-1	634	3754	3950	1565	4523	14426
SSF-708	634	3563	3779	1381	4332	13689
P.Kusuma	673	3798	4030	1449	4604	14554
SSF- 748	634	3711	3896	1527	4412	14180
PBNS-12	673	3615	3914	1546	4604	14351
NARI-57	673	4102	3941	1633	4583	14932
NARI-6	634	3841	4004	1594	4503	14576

Table 3. Stagewise photothermal units ($_0$C) requirement of safflower

Treatments	Phenological growth stage					
	Sowing - Germination	Germi.- Rosette	Rosette - Bud Ini.	Bud ini – 50 % flowering	50 % flower- P.mat.	Total
Sowing dates						
D_1:FF Sept.	977	4870	5704	2069	6125	19746
D_2:SF Sept.	923	5153	5204	2066	5630	18976
D_3:FF Oct.	988	4877	4619	1690	4921	17094
Varieties						
Annigeri-1	938	4947	5201	1989	5576	18652
SSF-708	938	4690	4974	1755	5342	17699
P.Kusuma	996	5005	5309	1841	5675	18826
SSF- 748	938	4889	5129	1940	5441	18337
PBNS-12	996	4760	5153	1965	5675	18549
NARI-57	996	5414	5189	2076	5650	19325
NARI-6	938	5064	5273	2026	5552	18853

Table 4. Leaf area index of safflower under different sowing dates and varieties at different physiological growth stages (Data of two years)

Treatments	Leaf area (cm^2) and LAI									
	Germination		**Rosette**		**Bud Initiation**		**50 % flowering**		**Physiological maturity**	
Sowing Dates										
D_1:FF Sept	4.26	0.005	279	0.31	1557	1.73	1573	1.75	733	0.81
D_2:SF Sept	5.09	0.006	240	0.27	1402	1.56	1443	1.60	641	0.71
D_3:FF Oct	4.87	0.005	180	0.20	1110	1.23	1136	1.26	432	0.48
SE ±	0.36		19		55		37		17	
CD (p= 0.05)	-		55		166		110		51	
Varieties										
Annigeri-1	4.57	0.005	198	0.22	1432	1.59	1486	1.65	641	0.71
SSF-708	5.96	0.007	287	0.32	1642	1.82	1663	1.85	593	0.66
P.Kusuma	4.61	0.005	233	0.26	1246	1.38	1257	1.40	478	0.53
SSF- 748	5.16	0.006	312	0.35	1781	1.98	1806	2.01	795	0.88
PBNS-12	4.42	0.005	299	0.33	1391	1.55	1414	1.57	542	0.60
NARI-57	4.38	0.005	139	0.15	911	1.01	936	1.04	473	0.53
NARI-6	4.09	0.005	161	0.18	1091	1.21	1124	1.25	692	0.77
SE ±	0.68		20		59		51		54	
CD (p= 0.05)	-		58		178		153		162	
CV %	6.34		10.4		12.4		16.3		18.4	

Table 5. Dry matter production of safflower under different sowing dates and varieties at different physiological growth stages (Data of two years)

Treatments	Dry matter production (g $plant^{-1}$)				
	Germination	**Rosette**	**Bud Initiation**	**50 % flowering**	**Physiological maturity**
Sowing Dates					
D_1:FF Sept.	0.011	3.06	69.92	88.94	99.32
D_2:SF Sept.	0.014	2.83	62.83	77.36	86.17
D_3:FF Oct.	0.015	2.75	57.33	59.73	70.59
SE ±	0.002	0.09	3.17	5.19	5.88
CD (p= 0.05)		0.30	9.50	15.60	17.60
Varieties					
Annigeri-1	0.009	3.03	61.29	73.21	82.35
SSF-708	0.014	3.15	72.88	82.63	91.44
P.Kusuma	0.016	2.63	56.42	69.74	78.88
SSF- 748	0.011	2.21	76.32	85.18	94.32
PBNS-12	0.013	3.46	53.39	59.34	68.48
NARI-57	0.014	3.22	66.97	79.87	95.50
NARI-6	0.016	2.47	56.24	77.39	86.53
SE ±	0.003	0.10	2.32	2.05	1.72
CD (p= 0.05)	-	0.32	6.97	6.16	5.15
CV %	6.18	9.31	14.67	17.26	19.73

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