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Genotypes and sowing dates mediated changes in growth and phenology of Safflower (*Carthamus tinctorius* L.) in non-traditional area of Northern Telangana Zone (NTZ)

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Abstract
A field experiment entitled "Evaluation of safflower (*Carthamus tinctorius* L.) cultivars under different sowing dates in non-traditional area of Northern Telangana Zone (NTZ)" is carried out during rabi, 2022-23 in sandy clay loam soils of Regional Agricultural Research Station, Polasa, Jagtial. The main aim of experiment is to find out, suitable safflower cultivar and optimum sowing window of safflower under different sowing dates in non-traditional area of Northern Telangana Zone. Ten treatment combinations were used in the factorial randomized block design of the experiment, which was replicated three times. The treatments includes factor-1 having two genotypes i.e., G_1: ISF-764, G_2: TSF-1 and factor - 2 having five sowing dates i.e., D_1:15th October, D_2:30th October, D_3:15th November, D_4:30th November, D_5:15th December. The results of the research revealed that, among two genotypes plant height was significantly highest with G_2: TSF-1 (121.7 cm) due to its genetic character and dry matter production (1252.9 g m^{-2}), leaf area index (1.84), SPAD chlorophyll readings (18.8). Crop sown on D_2:30th October showed significantly higher plant height (108.9 cm), LAI (2.15), dry matter production (1352 g m^{-2}), SPAD chlorophyll readings (18.3) compared to other dates of sowing but it was also statistically on par with crop sown on D_1:15th October for most of the parameters. Lowest growth parameters was noticed with crop sown on D_5: 15th December. The interaction effect between genotypes and dates of sowing showed no significant effect on all parameters. Among genotypes G_1: ISF-764 showed maximum number of days to attain rosette stage (26), flowering stage (73) and physiological maturity (108). Interaction of dates of sowing and genotypes showed no significant effect on number of days to attain rosette stage, flowering stage and physiological maturity. The number of days to attain different phenophases varied with dates of sowing days to rosette stage (28), flowering stage (78) and physiological maturity (111) were significantly higher with crop sown on D_1: 15th October compared to other dates of sowing and lowest number of days to rosette stage (22), flowering stage (67) and physiological maturity (104) was recorded with crop sown on D_5: 15th December.

Keywords: Safflower, genotype, sowing date, growth and phenology

1. Introduction
India is the fourth largest producer of oilseeds in the world in terms of output and is second in cultivated area next to food crops. Safflower (*Carthamus tinctorius* L.) is one of the most important oilseed crop owing to its various uses and special qualities. India is the major safflower growing country and contributes about 60 percent of the total world production. In the nation, the crop is mostly farmed in Maharashtra, Karnataka and portions of Andhra Pradesh, Madhya Pradesh, Orissa, Bihar and other states.

The major safflower growing states are Maharashtra and Karnataka, which contribute more than 90% of India's production. India is the largest producer of safflower (2.0 lakh tonnes) in the world with highest acreage (4.3 lakh hectares) but with an average productivity of 465 kg ha^{-1} (Times of Agriculture today 2025) [15]. In Telangana safflower is growing in an area of 7590 acres with 2732 MT of production. The major reasons for low productivity of safflower is correct cultivar and sowing date has not been selected.

To maximize crop productivity, the right cultivar acts as a pivot around which all other agricultural characteristics are modified. Thus, the first and most important factor influencing crop average yield is selecting an appropriate cultivar. The combination of genetic factors controlling growth and yield potential results in the ability to respond to different agronomical aspects that complement yield, provided all other inputs are adequately supplied. Because the edaphoclimatic circumstances of one location may not apply to another, the appropriate cultivar must be selected for the area.

A crucial management element in any cropping system is cultivar selection, which is particularly more important when it comes to the date of crop production (Soleymani *et al*., 2011) [13]. Not every variety is appropriate for both early and late sowing. Ecological considerations and production methods play a major role in determining the productivity and quality characteristics of safflower. Safflower cultivars and sowing dates have been found to differ based on ecological conditions (Daltalab *et al*., 2013) [4].

In order to cultivate safflower successfully and affordably in any area, it is important to identify the right types and growth methods. Choosing the right time to plant is an important growing strategy. The date of sowing is one of the key factors that determines yield. To guarantee that the plant grows vegetatively in an environment with adequate temperature, rainfall and day length, it is crucial to choose the right sowing date. According to earlier research, later sowing dates related to lower seed and oil yields (Samanci and Ozkaynak, 2003).

Delays in sowing resulted in lower seed yields and fewer seeds per head. According to Akhter *et al*. (2015) [1], incorrect vegetative growth and excessive temperatures at later stages of crop growth caused forced maturity and low productivity when seeding was delayed. According to Beech and Norman (1963) [3], late-sowing safflower plants decreased vegetative vigour and shorter reproductive period were factors in the drop in seed and oil yield. Additionally, selecting the ideal planting date requires a thorough understanding of ecological and environmental growing factors (Khajehpour 1998) [9]

2. Materials and Methods

The field experiment entitled "Evaluation of safflower (*Carthamus tinctorius* L.) cultivars under different sowing dates on yield and yield attributes in non-traditional area of Northern Telangana Zone (NTZ)", an experiment was conducted at RARS, Polasa, Jagtial during Rabi, 2022-23. The experiment was laid out in factorial randomized block design with ten treatment combinations by replicating thrice. The treatments includes two i.e., factor-1 having two genotypes G_1: ISF-764, G_2: TSF-1 and factor -2 having five sowing dates D_1: 15th October, D_2: 30th October, D_3: 15th November, D_4: 30th November, D_5: 15th December. The soil of the experiment field was slightly alkaline in reaction, sandy clay loams in texture, low in organic carbon (0.43%), low in available nitrogen (179.2 kg ha^{-1}) and available phosphorus (9.6 kg ha^{-1}) but high in available potassium (310.2 kg ha^{-1}). For ensuring good germination, healthy and good quality seeds were used with 20 kg ha^{-1} with planting geometry of 45 x 20 cm. The recommended dose of fertilizer (40 N + 25 P_2O_5 kg ha^{-1}) was applied in safflower. Full dose of P_2O_5 and half dose of N were applied at the time of sowing in the furrow below the seed. Remaining half dose of N was applied at stage of crop at 35- 40 DAS. Soil moisture was not sufficient for crop growth so three uniform irrigation was given to the crop at rosette stage, flowering stage and at seed development stage. The data was analyzed by the method of "Analysis of Variance" as described by Panse and Sukhatme.

3. Results and Discussion

3.1 Plant height (cm)

The data on mean plant height (cm) recorded at various crop growth stages are presented in Table 1, The periodical height of the plants was measured at rosette stage, flowering stage and at maturity. The increases in height due to different treatments have been given in the table. According to the data, the height of the plants climbed gradually as the crop advanced till harvest. The data presented in Table 1, revealed that different genotypes of safflower showed significant variation in plant height at all growth stages. Significantly more plant height of safflower was observed with genotype TSF-1 at rosette stage (11.9 cm), flowering stage (112.3 cm) and at maturity stage (121.7 cm) compared to genotype ISF-764 at rosette stage (9.5 cm), at flowering stage (80.9 cm) and at maturity stage (90.9 cm). The effect of sowing dates on plant height was found significant at rosette stage and also recorded no significant at flowering stage and maturity stage (Table 1). Maximum plant height was recorded with 30th October (11.2 cm) sown crop and on par each other with the dates of sowing of 15th October (10.7 cm), 15th November (10.5 cm) and 30th November (10.6 cm), 15th December (10.5 cm) at rosette stage. Highest plant height was recorded with 30th October (97.7,108.9 cm) at flowering, maturity stages. Lowest plant height was obtained 15th December (91.8, 104.5 cm) flowering, maturity stages. Delay in sowing drastically reduced the plant height of the crop due to adverse weather conditions. Soleymani *et al*., (2011) [13] noted that, early sowing of safflower recorded highest plant height than late sowing. Odivi *et al*., (2013) [10] reported that, the first sowing date had the maximum plant height compared to other sowing dates. The interaction effect of genotypes and sowing dates of safflower did not show any significant difference in plant height.

Table 1: Plant height (cm) of safflower at different growth stages as influenced by genotypes and sowing dates.

Treatments	Crop Growth Stages		
	Rosette stage	Flowering stage	Maturity stage
Factor- 1: Genotypes			
G_1: ISF - 764	9.5	80.9	90.9
G_2: TSF - 1	11.9	112.3	121.7
S.Em ±	0.07	1.05	0.98
CD (P = 0.05)	0.21	3.15	2.95
Factor- 2: Sowing dates			
D_1: 15th October	10.7	95.8	106.7
D_2: 30th October	11.2	97.7	108.9
D_3: 15th November	10.5	93.3	105.5
D_4: 30th November	10.6	96.7	106.1
D_5: 15th December	10.5	91.8	104.5
S.Em ±	0.11	1.66	1.55
CD (P = 0.05)	0.34	NS	NS
Interaction (G x S)			
S.Em ±	0.16	2.35	2.20
CD (P = 0.05)	NS	NS	NS

3.2 Phenology

Genotypes didn't show any significant influence on phenology of safflower. But sowing dates exert significant influence on days taken to attain each phonological stage (Table 2). More number of days were taken to attain rosette stage (28), flowering stage (78) and maturity stage (111) under 15th October (D_1) sown crop compared to other sowing dates 30th October, 15th November and 30th November, 15th December. Less number of days were taken to attain rosette stage (22), flowering stage (67)

and maturity stage (104) under 15th December (D_5) sown crop (Table 2).

Table 2: Number of days to attain different phonological stages of safflower as influenced by genotypes and sowing dates.

Treatments	Crop Growth Stages		
	Rosette stage	Flowering stage	Maturity stage
Factor- 1: Genotypes			
G_1: ISF - 764	26	73	108
G_2: TSF - 1	25	72	107
S.Em ±	0.3	0.7	0.4
CD (P = 0.05)	NS	NS	NS
Factor- 2: Sowing dates			
D_1: 15th October	28	78	111
D_2: 30th October	27	76	109
D_3: 15th November	26	74	108
D_4: 30th November	24	71	106
D_5: 15th December	22	67	104
S.Em ±	0.4	1.0	0.7
CD (P = 0.05)	1.2	3.1	1.94
Interaction (G x S)			
S.Em ±	0.6	1.5	0.9
CD (P = 0.05)	NS	NS	NS

3.3 Leaf Area Index (LAI)

Experimental data collected on LAI under different genotypes and sowing dates were analyzed statistically and the results were presented in the Table 3 The data revealed that the effect of genotypes on leaf area index was found to be significant at all stages of crop growth except at maturity stage. At rosette stage and flowering stage, the genotype TSF-1 (0.36 and 3.53) is having highest leaf area index and on par with genotype ISF-764 (0.25 and 2.48). The effect of sowing dates on leaf area index was shows significant at all growth stages except at maturity stage (Table 3), the LAI decreased with delay in sowing. Maximum LAI was observed in 30th October (D_2) sown crop at rosette stage (0.34), flowering stage (3.28) and at maturity stage (2.15). Crop sown on 15th December (D_5) showed the lowest LAI at rosette stage (0.27), flowering stage (2.76) and at maturity (1.41). Remaining sowing dates are D_1, D_3, and D_4 on par with each other when crop sown on 30th October D_2 at rosette and flowering stages. The increased LAI in early sowing might be due to increased plant height. Soleymani *et al*., (2011) [13] was noted that, early sowing of safflower recorded highest leaf area than late sowing. During the study, LAI was not influenced by the combined effect of genotypes and sowing dates.

Table 3: Leaf area index (LAI) of safflower at different growth stages as influenced by genotypes and sowing dates.

Treatments	Crop Growth Stages		
	Rosette stage	Flowering Stage	Maturity stage
Factor- 1: Genotypes			
G_1: ISF - 764	0.25	2.48	1.64
G_2: TSF - 1	0.36	3.53	1.84
S.Em ±	0.01	0.05	0.14
CD (P = 0.05)	0.02	0.15	NS
Factor- 2: Sowing dates			
D_1: 15th October	0.32	3.12	1.94
D_2: 30th October	0.34	3.28	2.15
D_3: 15th November	0.30	3.01	1.68
D_4: 30th November	0.29	2.88	1.53
D_5: 15th December	0.27	2.76	1.41
S.Em ±	0.01	0.08	0.23
CD (P = 0.05)	0.03	0.24	NS
Interaction (G x S)			
S.Em ±	0.02	0.12	0.32
CD (P = 0.05)	NS	NS	NS

3.4 Dry matter production (g m^{-2})

Data pertaining to genotypes and sowing dates on dry matter (DM) production was analysed statistically and found to be significant at all the growth stages (Table 4). The data presented in Table 4 revealed that the effect of genotypes on dry matter production (g m^{-2}) was found to be significant at all stages of crop growth. Genotype TSF-1 accumulated maximum dry matter at rosette (39.8 g), flowering (1025.4 g) and at maturity (1252.9 g) stages. Minimum dry matter accumulation seen with genotype ISF-764 at rosette (31.6 g), flowering (774.5 g) and at maturity (1007.5 g) stages. During the study, significantly higher dry matter accumulation was observed at all the growth stages with 30th October (D_2) sown crop at rosette (46.5 g), flowering (1158.6 g) and at maturity (1352.1 g). While, lowest dry matter accumulation was noticed with 15th December (D_5) sown crop at rosette (27.6 g), flowering (670.5 g) and at maturity (908.9 g). At all the crop growth stages of safflower the dry matter production was higher under early sown crop *i.e*., D_2: 30th October due to favorable weather conditions and lowest dry matter production at all the stages was observed under delayed sowing *i.e*., D_5: 15th December. These results were corroborative the findings of Soleymani *et al*., (2011) [13]. High temperatures during the reproductive stage cause an increase in respiration, which increases the loss of stored food material, reducing fresh weight and decreasing shoot length and dry weight with a corresponding fall in leaf, stem, and pod dry weight (Barla *et al*., 2020) [2]. While, early sowing has resulted in higher dry matter production might be due to the cumulative effects of higher plant heights and favorable meteorological circumstances, such as longer days and more bright sunshine hours. These factors may have improved photosynthesis, which in turn increased dry matter output. The production of dry matter gradually increased as crop duration increased, while it reduced as sowing was delayed (Hasan *et al*., 2019) [8]. Interaction effect between genotypes and sowing dates on dry matter production was found to be not significant.

Table 4: Dry matter (g m^{-2}) production of safflower at different growth stages as influenced by genotypes and sowing dates.

Treatments	Crop Growth Stages		
	Rosette stage	Flowering Stage	Maturity stage
Factor- 1: Genotypes			
G_1: ISF - 764	31.6	774.5	1007.5
G_2: TSF - 1	39.8	1025.4	1252.9
S.Em ±	0.90	23.71	13.05
CD (P = 0.05)	2.70	70.91	39.12
Factor- 2: Sowing dates			
D_1: 15th October	39.6	993.7	1214.2
D_2: 30th October	46.5	1158.6	1352.1
D_3: 15th November	34.2	898.5	1133.3
D_4: 30th November	30.7	778.3	1042.6
D_5: 15th December	27.6	670.5	908.9
S.Em ±	1.43	37.43	20.64
CD (P = 0.05)	4.28	112.07	61.81
Interaction (G x S)			
S.Em ±	2.02	52.93	29.18
CD (p = 0.05)	NS	NS	NS

3.5 SPAD chlorophyll meter reading (SCMR)

A leaf greenness index is called SPAD. The amount of leaf chlorophyll, which measures the photosynthetic activity of leaves and is used to assess the crop's potential for production, was measured using a SPAD meter. Enhanced photosynthetic efficiency of the crop is indicated by higher chlorophyll concentration in the leaves, which affects crop growth and yield. Data pertaining to genotypes and sowing dates on SPAD chlorophyll meter readings (SCMR) was analysed statistically and found to be significant at all the growth stages (Table 5). The data presented in Table 5 indicated that the effect of genotypes on SPAD chlorophyll meter reading (SCMR) was found to be significant at all stages of crop growth. The highest SPAD was noticed with genotype TSF-1at rosette (35.4), flowering (44.3) and at maturity (18.8) growth stages. The lowest SPAD was recorded with genotype ISF-764 at rosette (31.9), flowering (40.7), and at maturity (15.3) growth stages. Effect of sowing dates registered a significant effect on SPAD chlorophyll meter readings (SCMR) at all stages of crop growth. The maximum SPAD readings were observed with 30th October (D_2) sown crop at rosette (37.3), flowering (47.5) and at maturity (18.3). But, lowest SPAD was noticed with 15th December (D_5) sown crop at rosette (30.5), flowering (37.4) and at maturity (16.1). At rosette and maturity stages D_1, D_3 and D_4, D_5 dates of sowing were on par each other. The interaction effect of genotypes and sowing dates of safflower did not show any significant difference in SPAD chlorophyll meter reading (SCMR).

Table 5: SPAD chlorophyll readings of safflower at different growth stages as influenced by genotypes and sowing dates.

Treatments	Crop Growth Stages		
	Rosette stage	Flowering stage	Maturity stage
Factor- 1: Genotypes			
G_1: ISF - 764	31.9	40.7	15.3
G_2: TSF - 1	35.4	44.3	18.8
S.Em ±	0.35	0.38	0.17
CD (P = 0.05)	1.04	1.15	0.53
Factor- 2: Sowing dates			
D_1: 15th October	35.2	45.1	17.5
D_2: 30th October	37.3	47.5	18.3
D_3: 15th November	33.7	42.5	16.8
D_4: 30th November	31.9	40.1	16.4
D_5: 15th December	30.5	37.4	16.1
S.EM ±	0.55	0.61	0.28
CD (0.05)	1.65	1.82	0.84
Interaction (G x S)			
S.Em ±	0.78	0.86	0.40
CD (P = 0.05)	NS	NS	NS

4. Conclusion

The above results conclude that combination of genotype TSF-1 sown on 15th and 30th October recorded higher, Growth parameters like plant height, LAI, dry matter production and SPAD chlorophyll readings. From the study it can be concluded that combination of genotype TSF-1 sown on 15th and 30th October performed best among all other treatment combinations. It is more suitable for Northern Telangana Zone (NTZ).

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