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Growth and yield of safflower genotypes grown under different sowing windows

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Abstract
A field investigation was conducted at Oilseed research unit, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola during rabi season 2022-23 with an object to find out suitable sowing date for safflower crop and to find out suitable varieties of safflower. The experimental site was fairly uniform in topography with clayey in texture and slightly alkaline in reaction. It was low in available nitrogen, medium in available phosphorus and rich in potash with moderate organic carbon. The experiment was laid out with twelve treatment combinations in split plot Design with three replications. Main plot consists of four sowing dates (S) *viz*. sowing in 39th MW (S_1), 41th MW (S_2), 43th MW (S_3), 45th MW (S_4) and sub plot consist of three varieties namely AKS-207 (V_1), PKV-Pink (V_2) and AKS-351 (V_3).
The differences were significant among all the sowing dates in respect of the seed, straw and biological yield. The highest growth attributes, seed yield (2160 kg ha^{-1}), straw yield (5590 kg ha^{-1}) and biological yield (7750 kg ha^{-1}) were recorded in 41st MW (S_2). The next suitable sowing date was observed to be sowing in 43th MW (S_3) in respect of seed, straw and biological yield. Quality parameter characters *viz*. protein content, protein yield and oil content, oil yield was significantly higher with sowing in 41st MW (S_2) followed by sowing in 43rd MW (S_3), 45th MW (S_4) and 39th MW (S_1). Sowing of safflower during the 41st MW (S_2) recorded higher oil and protein yield, GMR (Rs. 125553), NMR (Rs. 90876) and B: C ratio (3.62) compared to sowing in 43rd MW (S_3), 45th MW (S_4) and 39th MW (S_1). Variety AKS-351 (V_3) showed significant improvement in growth attributes, yield attributes and recorded highest seed oil and protein yield, GMR (Rs. 112391), NMR (Rs. 77978) and B:C ratio (3.26) as compared to PKV-Pink and AKS-207.

Keywords: Sunflower, genotypes, sowing window

Introduction
Safflower (*Carthamus tinctorius* L.,) is an annual oil crop that is adapted to droughty climatic conditions (Li and Mundel, 1996). In India, safflower is grown on a 5.17 lakh ha area with a production of 4.36 lakh metric tons and a productivity of 834 kg ha^{-1} (Anonymous 2021) [1]. In Maharashtra, safflower is grown on a 1.71 lakh ha area with a production of 9.9 lakh metric tons and a productivity of 579 kg ha^{-1}. In Vidarbha, safflower is grown on an area of 8.1 lakh ha with a production of 5.2 lakh metric tons and a productivity of 650 kg ha^{-1}.
The major states where safflower is grown in India are Maharashtra, Karnataka, parts of Andhra Pradesh, Madhya Pradesh, Orissa, Bihar, etc. (Anonymous 2021) [1]. Maharashtra is the highest producer of safflower, with a total production of 63 percent from the largest growing area of 67 percent, followed by Karnataka (32% in production from a 27% area). In Maharashtra, safflower is mainly grown in Marathwada and Vidarbha region. Buldhana occupies a large area under safflower. Today, it is also grown in parts of Akola, Amravati, and Yavatmal districts. The high productivity of safflower is an outcome of major agronomical practices such as sowing dates and genotypes. The changing climatic conditions responsible for changes in the sowing schedule of crops and cropping systems. Sowing dates mean the effects of edaphic factors and all the environmental conditions on a large scale on the growth and yield of all field crops, which differ widely from region to region. Moreover, sowing dates are considered the most important affecting factors for safflower. Early sowing of safflower suffers from wilt or rust disease, while late sowing increases the chances of attack by aphids.

Appropriate cultivars serve as a pivot around which all other parameters of agriculture are adjusted in order to achieve the highest yield of crop. Finding a suitable cultivar is the first and most crucial aspect affecting the crop's average yield. The capacity to respond to various agronomical elements that are complementary to yield, assuming all other inputs are sufficiently supplied, is the result of the interaction of genetic factors governing growth and yield potential. The right cultivar must be chosen for the area because the climatic conditions of one place may not apply to another. "Cultivar selection is a key management component in any cropping system even more critical in sowing dates for crop production". All the varieties may not be suitable for timely as well as late sowing. The yield and quality properties of safflower are largely determined by ecological factors and cultivation techniques. It was reported that the sowing date and cultivars of safflower vary depending on ecological conditions (Datalab *et al.* 2013) [3]. It is equally important to choose the right sowing date. Utilizing advantageous climatic conditions to their fullest and protecting plants during their growth phases from unfavorable environmental influences are both essential for enhancing crop output. Since temperature and day length have a greater impact on the length of development stages, the sowing date can be chosen to provide for the best temperature and day length for the various stages of plant growth. It is also essential to choose the right planting date by having appropriate knowledge of ecological and environmental growing elements. Crop planting depends on rainfall and soil moisture availability in dry-land environments. Early sowing makes better use of the moisture in the soil. The crop displayed early vigour, growth, and development, which led to a greater yield. The yield fall rate varies from 4 to 80 kg day^{-1} ha^{-1} as a result of delayed seeding. Because pests and diseases are more common, germination is poor due to low temperatures, plant stands are weak, and there is a severe terminal drought, delayed sowing reduces yield.

Intensive work is necessary to improve the production potential of the safflower crop to make it a strong competitor in the general oilseed trade. Systematic agronomic factors such as time of sowing and varieties are of paramount importance for improving safflower yield. The time of sowing had a very significant effect on total dry matter production, seed yield, and harvest index of safflower (Gangasaran *et al.*, 1986) [6]. Early sowing increased the oil content due to the effect of high temperatures and low soil moisture prevailing at the later stages of capitulum development under late sowing (Bastia *et al.*, 1999) [2]. Sowing time is a major agronomic factor affecting both seed and oil yield in safflower (Tomar, 1995) [13].

Sowing at the optimum time is very important for higher yields. However, unpredicted weather and delayed harvesting of previous *kharif* crop delays safflower sowing, which adversely affect crop growth and yield. Growing the safflower crop under late-sown conditions is possible only by growing short-duration varieties. However, late-sown crop yields are considerably reduced. Safflower is mainly grown in the *rabi* season on residual moisture. The area under safflower in the Vidarbha region is increasing, but the average yields are low. Improved varieties of safflower with high yield potential have evolved and may respond to different soil, plant, and climatic management complexes. The production potential of these promising varieties of safflower needs to be exploited under the ecological circumstances of Vidarbha. The crop responds to seeding time in all seasons, and its performance is pronounced when sown at the right time. The present investigation on different dates of sowing might have a significant effect on the growth, yield, quality, oil content, and economics of safflower because sowing at different dates ameliorates the microclimate to a reasonable extent.

Materials and Methods

A field experiment was laid out in the Gambhir Baba field oilseed research unit, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, during the *rabi* season of 2022-2023. The topography of the field was clay loam soil fairly uniform and level. The pH of the soil was 8.24, which indicated that it was slightly alkaline in reaction. The soil was low in available nitrogen 172.7 kg ha^{-1} (Subbiah and Asija 1956) [12], medium in available phosphorus 21.4 kg ha^{-1}, and rich in available potash 453.6 kg ha^{-1} (Jackson, 1967) [8]. It was moderate in organic carbon. Akola is situated in the subtropical zone at latitude of 22.42° N and a longitude of 77.02 °E. The altitude of the place is 307.41 m above the mean sea level. The climate of the area is semi-arid, characterized by three distinct seasons: summer, which becomes hot and dry from March to May, the warm and rainy monsoon from June to October; and winter, which is mild and cold from November to February. The details of the treatment combination involving two factors *viz*., sowing dates and varieties are as follows. The experiment was carried out in split plot design with twelve treatment combinations and three replications.

Treatment **Main plot :- Sowing dates**	Symbol
i. Last week of September (39 MW- 28/09/2022)	S_1
ii. 2 nd week of October (41 MW-12/10/2022)	S_2
iii. 4 th week of October (43 MW-28/10/2022)	S_3
iv. 2 nd week of November (45 MW-09/11/2022)	S_4
Sub plot :- Varieties	
i. AKS -207	V_1
ii. PKV Pink	V_2
iii. AKS - 351	V_3

Several agro-meteorological indices developed by utilizing various meteorological elements are found in literature to study the crop environment relationships. The indices growing degree days (GDD), helio-thermal units (HTU), thermal use efficiency (HUE) The methods of computation of the indices are as under.

Growing Degree Days (GDD)

The growing degree days were calculated by simple accumulation of daily mean air temperature above a critical threshold temperature. It can be mathematically expressed as under.

$$GDD = \Sigma [(T\ max + T\ min)/2 - Tb$$

Where,
GDD = Growing degree days (day °C)
T max = Daily maximum temperature (°C)
T min = Daily minimum temperature (°C)
Tb = Base temperature (°C)

Helio-Thermal unit (HTU)

The value of helio-thermal unit representing the product of GDD and actual duration of bright sunshine hours (BSS) for a particular day as recorded by the sunshine recorder, used in place of the day length factor or maximum possible sunshine hour. This may be termed as actual photo thermal unit and expressed in following formula

$$HTU = GDD \times n$$

Where
n = actual duration of bright sunshine hours as recorded by sunshine recorder for a particular location.

Thermal use efficiency (TUE)
Thermal use efficiency of the crop in terms of grain yield and biomass yield was calculated treatment wise by dividing the grain yield and biomass yield of safflower by corresponding accumulated thermal units (GDD) of the treatment.

$$\text{Thermal use efficiency (kg/ ha/°C day)} = \frac{\text{Grain yield/Biological yield (kg/ha)}}{\text{Accumulated thermal units (°C day)}}$$

The statistical analysis of the data on various growth and yield characters studied in the investigation was carried out through the statistical analysis of variance technique as described by Panse and Sukhatme (1967) [9].

Results and Discussion
The development of phenophase is most essential component of the study of crop weather relationship of safflower crop and crop weather models, which can be used to specify the most appropriate rate and time of the specific development phase for maximization of crop yield.

Table 1: Comparison of phenological stages between date of sowing and genotype of safflower

Treatments	Days after sowing				
	P1	P2	P3	P4	P5
A) Date of Sowing (S)					
S_1 - Last week of Sept. (39th MW) 28/09/2022	7.21	48.67	75.22	89.22	135.22
S_2 - 2nd Week of Oct. (41st MW) - 12/10/2022	6.56	50.67	75.44	89.44	133.21
S_3 - 4th Week of Oct. (43rd MW) - 28/10/2022	7.54	49.33	74.56	82.89	129.83
S_4- 2nd Week of Nov. (45th MW) - 09/11/2022	7.38	50.11	74.33	88.00	127.58
B) Variety (*V*)					
V_1- AKS-207	7.12	48.75	76.92	88.50	133.24
V_2 - PKV PINK	7.01	50.58	75.58	88.67	136.31
V_3 - AKS-351	7.39	49.75	72.17	85.00	132.83

(P1- Days to emergence, P2- Days to branch initiation, P3- Days to flowering, P4 - Days to capitula initiation, P5 - Days to physiological maturity)

Safflower is basically a long day plant, determinate in habit with specific stages of development responsive to changing growing environment. Time of overlap of vegetative and reproductive growth is lesser in determinate type than indeterminate type. In this experiment, number of days taken to achieve different phenophases in safflower showed that number of days for different phenological stages decreased in case of vegetative and flowering stages and increased in case of capitula initiation and maturity stages with successive delayed sowings. However, as regards emergence, the germination across all the four sowings took place in 7 to 8 days with uniform optimum plant stand. Further, early sowing (39th MW) required more number of days for attaining various phenological stages reaching maturity in 135.22 days. Subsequent three sowings took 133.21, 129.83 and 127.58 days for maturity. This was due to cumulatively decreased duration of phenophases in response to the weather variables in each of the successive delayed sowing. The maturity period averaged was more in variety PKV Pink (136.21 days) followed by AKS-207 (133.24 days) and AKS-351 (132.83 days). This was more due to inherent genetic characteristics of the variety rather than any other interacting factor.

Yield studies
Sowing dates significantly influenced the seed yield. Sowing in 41st MW (S_2) recorded significantly higher seed, straw and biological yield (2162, 5592 and 7754 kg ha^{-1}) over sowing in 43rd MW. Increase in seed, straw and biological yield with sowing 41st MW might be due to convenient temperature for longer time favourable for germination as well as vegetative and reproductive growth of plants and ultimately the resultant effect of contribution of different yield attributes to the yield. Similar finding were also reported by Deokar *et al*. (1984) [5] Patel *et al* (1996) [11], Patel *et al*. (1997) [10] and Hulihali *et al*. (1997) [7].

Table 2: Seed weight $plant^{-1}$, 100 seed weight, seed yield, straw yield, biological yield of safflower as influenced by various treatments.

Treatments	Seed wt $plant^{-1}$ (g)	100 seed weight (g)	Seed yield (kg ha^1)	Straw yield (kg ha^{-1})	Biological yield (kg ha^{-1})
A) Date of Sowing (S)					
S_1 - Last week of Sept. (39th MW) - 28/09/2022	12.5	4.82	1200	2852	4052
S_2 - 2nd Week of Oct. (41st MW) - 12/10/2022	25.1	5.24	2162	5592	7754
S_3 - 4th Week of Oct. (43rd MW) - 28/10/2022	21.7	5.23	1764	4400	6164
S_4- 2nd Week of Nov. (45th MW) - 09/11/2022	18.7	5.21	1577	3851	5428
SE (m) ±	0.30	0.01	1.99	3.45	5.26
CD (P=0.05)	1.04	0.04	6.87	11.94	18.20
B) Variety (*V*)					
V_1- AKS-207	18.7	5.89	1640	4080	5720
V_2 - PKV PINK	14.5	3.26	1442	3800	5242
V_3 - AKS-351	26.1	6.22	1945	4651	6596
SE (m) ±	0.37	0.01	0.77	1.88	2.36
CD (P=0.05)	1.11	0.03	2.31	5.63	7.07
C) Interactions (S x V)					
SE (m) ±	0.74	0.02	1.54	3.76	4.71
CD (P=0.05)	2.22	0.06	4.61	11.27	14.13

Seed yield was significantly influenced due to variety. Variety AKS-351 (V_3) recorded significantly higher seed, straw and biological yield (1945, 4651 and 6596 kg ha^{-1}) over varietyAKS-207 (V_1) and PKV Pink (V_2). Highest seed yield in AKS-351 (V_3), might be attributed to the higher values of the yield attributes *viz*. weight of seed capitla¹ and seed weight plant¹. The interaction effect between sowing dates and variety on seed yield was found to be significant.

Quality parameters

Table 3: Protein content and oil content of safflower as influenced by various treatments

Treatments	Protein content (%)	Protein yield (kg ha^{-1})	Oil content (%)	Oil yield (kg ha^{-1})
A) Date of Sowing (S)				
S_1 - Last week of Sept. (39th MW) - 28/09/2022	12.02	144.4	31.1	374.6
S_2 - 2nd Week of Oct. (41st MW) - 12/10/2022	12.32	265.5	31.3	672.0
S_3 - 4th Week of Oct. (43rd MW) - 28/10/2022	12.14	215.5	31.2	547.9
S_4- 2nd Week of Nov. (45th MW) - 09/11/2022	12.30	192.1	30.9	483.1
SE (m) ±	0.21	25.14	0.22	59.17
CD (P=0.05)	NS	75.44	NS	177.52
B) Variety (*V*)				
V1- AKS-207	12.18	200.4	30.7	503.2
V2 - PKV PINK	12.15	175.7	32.1	462.9
V3 - AKS-351	12.26	237.0	30.6	592.1
SE (m) ±	0.10	9.37	0.19	23.25
CD (P=0.05)	NS	28.09	0.58	69.70
C) Interactions (S x V)				
SE (m) ±	0.20	18.74	0.39	46.50
CD (P=0.05)	NS	NS	NS	NS

Data regarding the different sowing dates on protein and oil content found to be non significant. The interaction effect between sowing dates and variety on protein and oil yield was found to be non significant.

Data recorded on oil and protein yield (Kg ha^{-1}) as influenced due to different sowing dates and varieties. Data indicated that Variety AKS-351 (V_3) found recorded highest oil and protein yield over variety AKS-207 (V_1) and PKV Pink (V_2). The interaction effect between sowing dates and variety on oil yield were found to be non significant. The interaction effect between sowing dates and variety on protein yield were found to be non significant.

Agrometeorological indices

1. Growing degree day

In Table 4 data regarding phenophase wise growing degree days (GDD) and total growing degree days availed by different sowing time and variety are presented. The accumulated growing degree days to reach various growth stages showed variation among the dates of sowing and variety. The accumulated growing degree days were reasonably higher during reproductive stage as compared to vegetative stage.

Table 4: Growing Degree days (GDD °C), at different phonological stages safflower variety affected by different sowing dates.

Treatments	Phenological stages				
	Sowing to emergence	Emergence to branch initiation	Branch initiation to 50% flowering	50% flowering to capitula initiation	Sowing to physiological maturity
A) Date of Sowing (S)					
S_1 - Last week of Sept. (39th MW) - 28/09/2022	142	713	553	941	2349
S_2 - 2nd Week of Oct. (41st MW) - 12/10/2022	150	624	702	881	2357
S_3 - 4th Week of Oct. (43rd MW) - 28/10/2022	136	573	501	813	2023
S_4- 2nd Week of Nov. (45th MW) - 09/11/2022	108	688	487	934	2217
B) Variety (*V*)					
V_1- AKS-207	119	609	534	834	2096
V_2 - PKV PINK	121	763	519	948	2351
V_3 - AKS-351	150	837	476	1076	2539

The accumulated growing degree days (°C day) to reach various growth stages differed among the different sowing times. First sowing (S_2) availed higher GDD during emergence phase followed by S_1. S_1 and S_2 During vegetative phase early sown crop accumulated highest growing degree days followed by S_3 and S_4 it was lower under last two sowing (S_3 and S_4). During flowering phase again early sown crop (S_1) accumulated highest growing degree days closely followed by S_4 and it was lower under two sowings *viz*. (S_2 and S_3). Across the total growing period (emergence to physiological maturity) of the crop the highest heat units were accumulated by S_2 (2357 °C day) closely followed by S_1 (2349 °C day), S_4 (2217 °C day) and S_3 (2023 °C day). Amongst the variety, in respect of GDD availed across vegetative and capitula initiation phases, by and large AKS-351(V_3) availed more number of GDD followed by AKS-207 (V_1) and PKV Pink (V_2). Comparatively longer duration of each respective phenophase and total growth duration of the crop in the respective sowing time and variety caused higher accumulation of GDD.

2. Helio-thermal units (HTU)

The helio-thermal units (HTU) availed to reach various growth stages noticeably differed among sowing times. Among different crop phenophases, the accumulated HTUs were higher when cumulated across reproductive stage as compared to vegetative stage. Under all the sowings (S_1, S_2, S_3 and S_4), emergence to capitula initiation cumulatively availed more number of HTU as compared to the preceding phenophases. Overall, late sown crop

S_3. (43 MW) availed higher HTU (6322 °C day hour) followed by S_2 (5834 °C day hour), S_4 (5610 °C day hour) and S_1 (5168 °C day hour). This was mainly due to more number of sunshine hours available across emergence to capitula initiation stage in later sown crops.

Table 5: Helio-thermal units (°C hours) at different phonological stages safflower variety as affected by different sowing dates.

Treatments	Phenological stages				
	Sowing to emergence	Emergence to branch initiation	Branch initiation to 50% flowering	50% flowering to capitula initiation	Sowing to physiological maturity
A) Date of Sowing (S)					
S_1 - Last week of Sept. (39th MW) - 28/09/2022	752	1752	2965	4938	5168
S_2 - 2nd Week of Oct. (41st MW) - 12/10/2022	706	1810	2650	5724	5834
S_3 - 4th Week of Oct. (43rd MW) - 28/10/2022	1160	1889	2903	3983	6322
S_4- 2nd Week of Nov. (45th MW) - 09/11/2022	752	2206	2896	4941	5610
B) Variety (*V*)					
V_1- AKS-207	1221	2218	2517	5171	5703
V_2 - PKV PINK	647	1447	2543	6013	6803
V_3 - AKS-351	1015	1653	3427	4212	6825

For the variety, among different phenophases, similar trend prevailed as that observed under sowing times. Among different crop phenophases, the accumulated HTUs were higher when cumulated across reproductive stage as compared to vegetative stage. Amongst the variety, by and large AKS-351 (V_3) accrued more number of HTUs (6825 °C day hour) followed by PKV Pink (V_2) (6803 °C day hour) and AKS-207 (5703 °C day). Comparatively longer growth duration of crop coupled with greater sunshine hours in the respective sowing date and for the respective genotype caused higher accumulation of HTU.

3. Thermal use efficiency

Table 6: Thermal use efficiency (kg/ha/°c) at different phonological stages safflower variety as affected by different Sowing dates

Variety	Meteorological week				Mean
	39 th	41 th	43 th	45 th	
AKS-207	0.54	0.85	0.88	0.66	0.74
PKV Pink	0.57	0.73	0.66	0.61	0.64
AKS-351	0.41	0.11	0.10	0.84	0.87
Mean	0.51	0.56	0.87	0.71	

Amongst the sowing time, thermal use efficiency in terms of seed yield was found to be maximum (0.88 kg ha^{-1} °C day^{-1}) under 43rd MW sowing closely followed (0.85 kg ha^{-1} °C day^{-1}) by 41st MW sowing. It markedly decreased in the later sowings of 45th MW (0.66 kg ha^{-1} °C day^{-1}) and early sowings 39th MW (0.54 kg ha^{-1} °C day^{-1}).

Among the variety, thermal use efficiency in terms of seed yield was higher with V_1- AKS-207 (0.88 kg ha^{-1} °C day^{-1}) and V_3- AKS-351 (0.84 kg ha^{-1} °C day^{-1}) followed by V_2 -PKV Pink (0.73 kg ha^{-1} °C day^{-1}).

Economics of the treatments

Significantly highest gross monetary returns (Rs. 125553 ha^{-1}) and net monetary returns (Rs. 90876 ha^{-1}) were obtained in 41st MW (S_2) sowing as compared to sowing 39th MW (S_1), 43rd MW (S_3) and 45th MW (S_4) in sowing. Sowing in 43rd MW (S_3) was remain at par with sowing in 41st MW (S_2) in respect of GMR and NMR. Highest B: C ratio (3.62) was observed in in 41st MW (S_2) followed by 43rd MW (S_3) (2.99), 45th MW (S_4) (2.68) and 39th MW (S_1) (2.08). Similar findings reported by Patel *et al.* (1996) [11], Dashora and Sharma (2006) [4]. Data revealed that AKS-351 (V_3) recorded higher gross monetary returns and net monetary returns of Rs. 112391 ha^{-1} and Rs. 77978 ha^{-1} respectively over variety AKS-207 (V_1) and PKV-Pink (V_2). however, it was at par with AKS-207 (V_1). Variety AKS-351 (V_3) recorded highest B: C ratio (3.26) and variety PKV- Pink (V_2). recorded lowest B: C ratio (2.48).

Table 7: Economics of safflower as influenced by various treatments

Treatments	GMR (₹. ha^{-1})	NMR (₹. ha^{-1})	Cost of cultivation (₹. ha^{-1})	B:C Ratio
A) Date of Sowing (S)				
S_1 - Last week of Sept. (39th MW) - 28/09/2022	69815	36282	33533	2.08
S_2 - 2nd Week of Oct. (41ht MW) - 12/10/2022	125553	90876	34677	3.62
S_3 - 4th Week of Oct. (43th MW) - 28/10/2022	102496	68291	34205	2.99
S_4- 2nd Week of Nov. (45th MW) - 09/11/2022	91137	57165	33972	2.68
SE (m) ±	11340	11340	-	-
CD (P=0.05)	39237	39237	-	-
B) Variety (*V*)				
V_1- AKS-207	95410	61351	34059	2.80
V_2 - PKV PINK	83949	50131	33818	2.48
V_3 - AKS-351	112391	77978	34413	3.26
SE (m) ±	4376	4376	-	-
CD (P=0.05)	13117	13117	-	-
C) Interactions (S x V)				
SE (m) ±	8752	8752	-	-
CD (P=0.05)	26234	26234	-	-

Sowing of safflower variety AKS-351 in 41st meteorological week recorded highest yield and economic returns.

Conclusion

The study underscores the importance of phenophases in optimizing safflower yields, highlighting how different sowing dates and varieties impact crop development and productivity. Safflower's response to sowing time was evident, with early sowings generally requiring more days to maturity and yielding more. Sowing in the 41st MW proved most effective, delivering higher seed, straw, and biological yields, likely due to favorable temperature conditions. Among varieties, AKS-351 consistently outperformed others in seed yield and economic returns, demonstrating its superior performance in different environmental conditions. Overall, the research provides valuable insights for improving safflower cultivation strategies and maximizing yield potential through careful consideration of sowing dates and variety selection.

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