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EFFECT OF SOWING WINDOWS AND CULTIVARS ON GROWTH AND PHENOLOGY OF *KHARIF* SUNFLOWER (*HELIANTHUS ANNUUS* L.) CROP IN SCARCITY CONDITIONS

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ABSTRACT

The research investigates the influence of various treatments on the growth and phenology of *kharif* sunflower (*Helianthus annuus* L.) across two consecutive years, 2021 and 2022. The study examines the effects of different sowing windows, cultivars, and protective treatments on plant height, number of leaves plant^{-1}, total dry matter accumulation plant^{-1}, and number of days required to attain phenological stages. Results indicate that early sowing window (S_1-MW25) led to increased plant height, number of leaves plant^{-1}, and total dry matter accumulation, while delayed sowing resulted in decreased growth parameters. The cultivar V_3-Phule Bhaskar was performed superior in plant height, leaf count, and total dry matter production compared to other and plant in T_1-protected condition using insecticides consistently yielding higher growth parameters and phenology compared to unprotected conditions in scarcity zone.

Key words: *Kharif* sunflower, sowing window, cultivar, growth parameter, development

Introduction

The sunflower plant boasts a diverse composition, comprising oil (48-53 per cent), protein (14-19 per cent), and carbohydrates (18 per cent) (Nagaraj, 1995), making it a valuable resource utilized in numerous industries, including cooking oil production, cosmetics, and pharmaceuticals, manufacturing hydrogenated oil, making dyes and paints, manufacturing ethyl alcohol, growing yeast and cake for livestock feed (Kunduraci *et al*., 2010). Sunflower oil contains linoleic acid (60-65 per cent) and oleic acid (25-30 per cent), and protein contains globulins (55-60 per cent), albumins (17-23 per cent), glutelin (11-17 per cent) and prolamins (1-4 per cent), add to its nutritional profile.

India ranks fourth globally in sunflower cultivation by area, but its productivity ranks eighth due to lower output levels (Rai *et al*., 2016). In Maharashtra, oilseed crops occupying 16.68 per cent and 16.70 per cent of the total cultivated area in 2019-20 and 2020-21, respectively. In sunflower cultivation, Maharashtra accounted for 12.18 per cent of the total area in 2019-20 and 9.60 per cent in 2020-21. Specifically, sunflower cultivation in Maharashtra covered an area of 0.02 m ha, yielding 0.01 MT with a productivity of 570 kg ha^{-1} in 2020 (Anonymous, 2021). Rainfed agriculture is pivotal to India's economy and food security, encompassing 55 per cent of the net sown area and supporting 61 per cent of the total Indian farmer population. This agricultural method also sustains two-thirds of the country's livestock and contributes significantly to total food grain production. Despite India's considerable cultivation of sunflower, productivity remains a challenge, particularly in rainfed areas where environmental factors like inadequate and uneven rainfall, monsoon dependence, sowing windows significantly impact crop yields (Agele *et al*., 2003; Anjum *et al*., 2012). This introduction sets the stage for examining the multifaceted aspects of sunflower cultivation in India, exploring its nutritional profile, industrial applications, and the challenges posed by environmental conditions.

Material and Methods

The experiment was carried out at the Zonal Agricultural Research Station, Solapur, Maharashtra, during the *kharif* seasons of 2021 and 2022. The geographical location of the site was 17°41'N latitude; 75°56'E longitude and at the altitude of 483.6 meters MSL.Agro-climatically entire district comes under rain shadow area. The average annual rainfall of districts is 721.3 mm with 49 rainy days is distributed from second fortnight of June to second fortnight October.

The experiment utilized a split-split plot design with three replications. It encompassed eighteen treatment combinations, incorporating different sowing windows, varieties, and treatment measures. The main plot treatment comprised three sowing windows: S_1-25th MW (18 Jun - 24 Jun), S_2-30th MW (23 Jul - 29 Jul), and S_3-35th MW (27 Aug - 2 Sept). Sub-plot treatment included three varieties: V_1-SS-56, V_2-MSFH-17, and V_3-Phule Bhaskar. The sub-sub treatment consisted of T_1-Protected using insecticides-fungicides and T_2-Unprotected conditions. All cultivars were dibbled according to sowing windows, maintaining a spacing of 45 cm × 20 cm. The field soil, identified as vertisol (medium black) with good drainage and clayey loam texture, was slightly alkaline and had a depth of up to 90 cm.

The following periodical observations were conducted on five randomly selected plants in each plot, labeled and marked with pegs. These observations were recorded at 30, 45, 60, and 75 DAS and at harvest to assess growth attributes, and phenological stages to assess development. The plant height was measured from the base of the plant *i.e.* ground level to the tip of the fully opened upper leaf of the five randomly selected plants in each net plot with the help of meter scale and average height per plant^{-1} was worked out. The number of leaves plant^{-1} arising from main shoot were counted from five randomly selected five plants in each net plot and average number of leaves plant^{-1} was worked out.

The representative plant sample from each net plot was uprooted and roots were discarded for dry matter studies. The plant material was chaffed and labeled properly. Initially plant samples were sundried for two-three days followed by oven drying at a constant temperature of 60°C until constant dry weight was obtained. After weighing the material, the dry matter plant^{-1} was recorded.

The number of days to complete growth stages of sunflower *i.e.* fourth leaf stage, button stage, fifty per cent flowering, soft dough stage, hard dough stage and physiological maturitystage were recorded to asses plant development by observing plants from net plot.

Results and Discussion

Plant Height

The trend indicates an increase in plant height as the crop advanced in age, reaching 149.54 cm at harvest in 2021 and 150.58 cm at harvest in 2022, starting from 37.13 cm and 38.00 cm at 30 DAS, respectively (Table 1).

Table 1: Mean plant height (cm) as periodically influenced by different treatments in *kharif* sunflower.

Treatment	Mean plant height (cm)									
	2021 30 DAS	2022 30 DAS	2021 45 DAS	2022 45 DAS	2021 60DAS	2022 60 DAS	2021 75 DAQ	2022 75 DAS	2021 At Harvest	2022 At Harvest
Main Treatment										
S_1 =MW 25	38.06	38.38	66.16	66.47	104.22	104.06	148.03	148.44	151.06	151.10
S_2 =MW 30	35.86	37.61	64.62	65.62	99.94	103.17	143.28	146.56	146.76	150.08
S_3 =MW 35	37.46	38.00	65.67	66.14	103.83	103.56	147.38	147.00	150.81	150.59
SE (m) ±	1.06	0.38	0.82	0.43	1.12	0.39	0.92	0.77	1.38	0.46
CD 5%	3.39	1.21	2.62	1.36	3.56	1.23	3.62	2.51	4.41	1.46
Sub Treatment										
V_1 =SS-56	36.12	37.24	64.54	65.19	102.44	103.33	143.99	144.94	144.57	146.79
V_2 =MSFH-17	37.21	38.07	65.40	66.02	100.89	101.89	145.45	146.28	149.21	149.68
V_3 =Phule Bhaskar	38.05	38.67	66.51	67.02	104.67	105.59	149.26	150.78	154.84	155.27
SE (m) ±	0.56	0.47	0.57	0.53	1.21	1.14	1.06	0.88	2.90	2.43
CD 5%	1.72	1.45	1.76	1.63	3.73	3.50	3.25	2.70	8.95	7.48
Sub-Sub Treatment										
T_1 =Protected	37.92	38.71	66.66	67.16	103.93	104.81	147.08	149.17	150.81	152.06
T_2 = Un-protected	36.33	37.29	64.31	65.00	101.44	102.37	145.38	145.50	148.27	149.10
SE (m) ±	0.25	0.26	0.46	0.45	0.29	0.30	0.28	0.38	0.46	0.43
CD 5%	0.74	0.76	1.35	1.35	0.85	0.89	0.83	1.14	1.36	1.26
GM	**37.13**	**38.00**	**65.48**	**66.08**	**102.67**	**103.59**	**146.23**	**147.33**	**149.54**	**150.58**

• Effect of Sowing Windows

The higher plant height (151.06 cm and 151.10 cm) was recorded under S_1-MW 25 sown crop, over S_3-MW 35 (150.81 cm and 150.59 cm) and the lowest plant height was recorder by S_2-MW 30 (146.76 cm and 150.08 cm) during 2021 and 2022, respectively (Table 1). Sunflower plant height ranges in between 147 cm to 154 cm (Sur and Sharma, 1999). Demir (2019) recorded that the sunflower plant height was 141.82 cm to 151.18 cm in different growing season. Significantly taller plant was recorded by S_1-MW 25, but it was statically at par with S_3-MW 35 at 30, 45, 60, 75 DAS and at harvest. These findings highlight the stability of growth patterns across the two years, with S_1-MW 25 consistently demonstrating better performance, S_3-MW 35 following closely, and S_2-MW 30 displaying the least impressive growth. Increase in plant height due to utilization of available resources at early sowing, better use of rainfall and soil moisture. The result emphasized that the plant height of sunflower increased with early sowing dates but decreased with delayed sowing dates. These results were also supported by Dutta (2011), Baghdadi *et al*., (2014), Khandekar *et al*., (2018) and Dhakar *et al*., (2022).

• Effect of Varieties

It was observed that the cultivar V_3-Phule Bhaskar recorded significantly highest plant height (154.84 cm and 155.27 cm), over V_2-MSFH-17 (149.21 cm and 149.68 cm) and V_1-SS-56 (144.57 cm and 146.79 cm) during 2021 2022, respectively (Table 1). The disparity in plant among the cultivars appears to be genetic control. According to Unger (1986) and Ali *et al*., (2004), sunflower cultivars significantly influence plant height, indicating that this variability may stem from varietal characteristics.

• Effect of treatment

The T_1-protected treatment was significantly superior over T_2-unprotected treatment and recorded maximum plant height (150.81 cm and 152.06 cm) over T_2-unprotected (148.27 cm and 149.10 cm) treatments during 2021 and 2022, respectively (Table 1). At various stages, including 30, 46, 60, and 75 days after sowing, the plants under protection consistently displayed greater height. The data suggests a positive influence of protection on plant development throughout different growth stages.

Number of Leaves Plant^{-1}

The number of leaves plant^{-1} increased from 30 DAS (18.87) to 60 DAS (24.48) and decreased till at harvest (8.25) during 2021, while in 2022, it was increased from 30 DAS (19.73) to 60 DAS (24.86) and decreased till at harvest (8.45) (Table 2). The decline in leaf count at harvest signifies a natural senescence process, optimizing resource allocation for seed production.

• Effect of sowing windows

The maximum number of leaves plant^{-1} of sunflower was recorded in S_1-MW 25 (25.39 and 25.71) followed

Table 2: Mean number of leaves plant^{-1} as periodically influenced by different treatments in *kharif* sunflower.

Treatment	Mean number of leaves plant^{-1}									
	2021 30 DAS	2022 30 DAS	2021 45 DAS	2022 45 DAS	2021 60DAS	2022 60 DAS	2021 75 DAQ	2022 75 DAS	2021 At Harvest	2022 At Harvest
Main Treatment										
S_1 =MW 25	19.33	19.91	22.39	23.85	25.39	25.71	24.40	24.76	8.72	8.55
S_2 =MW 30	18.18	19.56	21.02	22.74	23.58	24.09	23.43	23.92	7.56	8.62
S_3 =MW 35	19.10	19.72	21.85	22.94	24.49	24.73	24.06	24.36	8.48	8.18
SE (m) ±	0.32	0.17	0.47	0.50	0.61	0.47	0.49	0.42	0.47	0.30
CD 5%	0.99	0.51	1.98	1.49	1.81	1.39	1.46	1.24	1.39	0.90
Sub Treatment										
V_1 =SS-56	17.89	18.17	21.42	22.76	23.99	24.48	23.20	24.16	7.94	8.30
V_2 =MSFH-17	18.79	20.18	21.53	22.98	24.26	24.68	23.85	23.64	8.27	8.14
V_3 =Phule Bhaskar	19.93	20.83	22.32	23.79	25.19	25.43	24.84	25.14	8.54	8.91
SE (m) ±	0.29	0.40	0.19	0.32	0.36	0.31	0.48	0.47	0.17	0.33
CD 5%	0.91	1.24	0.58	0.94	1.08	0.91	1.42	1.40	0.51	0.98
Sub-Sub Treatment										
T_1 =Protected	18.91	19.79	22.84	24.05	25.27	25.76	24.79	25.09	8.98	9.05
T_2 = Un-protected	18.84	19.67	20.67	22.31	23.70	23.96	23.14	23.60	7.53	7.85
SE (m) ±	0.02	0.04	0.23	0.26	0.26	0.24	0.26	0.27	0.29	0.32
CD 5%	0.05	0.11	0.68	0.78	0.78	0.72	0.76	0.81	0.85	0.94
GM	**18.87**	**19.73**	**21.76**	**23.18**	**24.48**	**24.86**	**23.96**	**24.34**	**8.25**	**8.45**

Table 3: Accumulation of total dry matter (g) as periodically influenced by different treatments in *kharif* sunflower.

Treatment	Accumulation of total dry matter (g)									
	2021 30 DAS	**2022 30 DAS**	**2021 45 DAS**	**2022 45 DAS**	**2021 60DAS**	**2022 60 DAS**	**2021 75 DAQ**	**2022 75 DAS**	**2021 At Harvest**	**2022 At Harvest**
Main Treatment										
S_1 =MW 25	98.73	99.44	171.62	172.79	306.57	309.94	393.99	397.20	408.63	411.79
S_2 =MW 30	88.01	88.58	160.37	162.00	237.72	241.07	324.47	328.20	345.73	349.02
S_3 =MW 35	88.56	89.16	156.06	158.68	231.82	234.59	305.49	308.22	335.21	338.64
SE(m) ±	0.23	0.17	0.20	0.17	0.14	0.19	0.18	0.10	0.09	0.34
CD 5%	0.89	0.67	0.80	0.67	0.56	0.77	0.70	0.38	0.36	1.33
Sub Treatment										
V_1 =SS-56	79.08	79.88	148.73	150.48	223.07	226.01	315.92	318.98	339.74	342.24
V_2=MSFH-17	91.30	91.99	160.73	162.64	260.80	263.93	339.86	343.34	354.58	358.89
V_3=Phule Bhaskar	104.91	105.30	178.60	180.35	292.24	295.66	368.18	371.31	395.24	398.32
SE(m) ±	0.09	0.11	0.13	0.14	0.11	0.12	0.28	0.21	0.28	0.26
CD 5%	0.29	0.34	0.41	0.42	0.32	0.35	0.87	0.63	0.85	0.81
Sub-Sub Treatment										
T_1 =Protected	91.97	92.69	163.08	165.05	259.50	262.66	342.78	345.60	364.23	367.67
T_2 = Un-protected	91.56	92.09	162.29	163.93	257.91	261.07	339.85	343.48	362.15	365.30
SE(m) ±	0.10	0.13	0.14	0.22	0.20	0.16	0.24	0.16	0.30	0.14
CD 5%	0.29	0.38	0.43	0.65	0.60	0.49	0.70	0.49	0.77	0.42
GM	91.77	92.39	162.68	164.49	258.70	261.86	341.32	344.54	363.19	366.48

by S_3-MW 35 (24.49 and 24.73) and S_2-MW 30 (23.57 and 24.09) during 2021 and 2022, respectively (Table 2). Ahmed *et al.*, (2015) recorded the mean number of leaves plant^{-1} in ranged of 20.00 to 25.66 plant^{-1} in different sowing windows. A significantly higher number of leaves was observed by 25th MW, yet it was statically at par with S_2-MW 30 and S_3-MW at 75 DAS and at harvest. The early sowing window showed significantly more leaves, possibly due to favourable weather condition of different weather parameters and uniform availability of moisture during crop growing period. The number of leaves decreased significantly with delay in sowing time. The similar results were recorded by Sur and Sharma (1999), Kumar *et al.*, (2005), Ahmed *et al.*, (2015) and Amin *et al.*, (2017).

- **Effect of varieties**

The study revealed a progressive increase in the number of leaves increased with advancing age of crop, it was significantly higher in cultivar V_3-Phule Bhaskar (25.19 and 25.43) over V_2-MSFH-17 (24.26 and 24.68) and V_1-SS-56 (23.99 and 24.48) during 2021 and 2022, respectively (Table 2). Comparing the cultivars within each year, V_3-Phule Bhaskar consistently outperforms the others in terms of leaf count, while V_1-SS-56 tends to have lower counts. These differences could be attributed to genetic variations. Similar findings resonate with prior research by Ali *et al.*, (2004) and Unger (1986).

- **Effect of treatment**

In both 2021 and 2022, the T_1-protected treatment consistently displayed a significantly higher number of leaves plant^{-1} (25.27 and 25.76) over T_2-unprotected treatment (23.70 and 23.96), respectively (Table 2). This superiority was evident across 30, 45, 60, 75 DAS and at harvest. This indicated that a potential positive impact of protective measures on leaf development.

Total Dry Matter Plant^{-1}

The accumulation of dry matter plant^{-1} was increases with the advancement of crop age up to harvest of the crop (Table 3). The rate was rapid during flowering and reproductive stages of the crop.

- **Effect of sowing windows**

The mean maximum value of dry matter was recorded significantly higher in S_1-MW 25 sown crop (408.63 g & 411.79 g) over S_2-MW 30 (345.73 g and 349.02 g) and the lowest in S_3-MW 35 (335.21 g and 338.64 g) during both 2021 and 2022, respectively (Table 3). The S_1-MW 25 was significantly superior over the S_2-MW 30 and S_3-MW 35 during all periodical growth of the crop. It might be due to suitable weather conditions of weather parameters during crop growth period. Ahmed *et al.*, (2015) recorded the dry matter in ranged of 350-430 g under different sowing windows. Data revealed that as the delay in sowing there is considerable reduction in mean total dry matter. These results are in line with the earlier work of Kumar (2005), Ahmed *et al.*, (2015) and Dhillon *et al.*, (2017).

• **Effect of varieties**

The cultivar V_3-Phule Bhaskar (395.24 g and 398.32 g) consistently displayed significantly higher total dry matter plant^{-1} over V_2-MSFH-17 (354.58 g and 358.89 g) and V_1-SS-56 (339.74 g and 342.24 g) during 2021 and 2022, respectively (Table 3). This indicates that the V_3-Phule Bhaskar utilized more efficiently moisture, light, temperature and produced maximum total dry matter by maximum solar radiation interception. The findings underscore the potential superiority of V_3-Phule Bhaskar in terms of biomass production, prompting further exploration into the factors contributing to this variation, such as genetic traits.

• **Effect of treatment**

The T_1-Protected treatment was recorded significantly highest mean dry matter plant^{-1} (364.23 g and 367.67 g) over the T_2-unprotected treatment (362.15 g and 365.30 g) during 2021 and 2022, respectively (Table 3). The mean dry matter accumulation plant^{-1} was increased with advancement of the crop age and it was recorded highest at harvest in both the year of experiment.

Number of Days Required to Attain Phenological Stages

The data pertaining to mean number of days required to attain phenological stages of sunflower as influenced by different treatments are presented in (Table 4) for 2021 and 2022.

• **Effect of sowing windows**

In 2021, the mean days required to attain various phenological stages differed among the cultivars. S_1-MW 25 demonstrated a prolonged time line, needing 44 days for button, 57 days for 50 per cent flowering, 66 days for soft dough stage, 78 days for hard dough stage, and 87 days for physiological maturity. S_3-MW 35 had slightly shorter durations, with 43, 55, 65, 77, and 85 days for the respective stages and S_2-MW 30 showed the shortest durations among the three cultivars, requiring 41, 52, 60, 71, and 78 days for the same stages. In 2022, the pattern persisted S_1-MW 25 continued to have the longest durations, ranging from 45 to 89 days for button, 50 per cent flowering, soft dough, hard dough, and physiological maturity. S_3-MW 35 exhibited 44, 57, 66, 79, and 88 days for the respective stages. S_2-MW 30 recorded, 43, 55, 64, 76, and 85 days for the same phenological stages (Table 4).

This prolonged duration in S_1-MW 25 is attributed to potentially more favorable early sowing conditions, ensuring adequate soil moisture during critical growth phases like flowering and grain development. The observed differences in the duration to reach phenological stages underscore the influence of sowing timing on crop development. This prolonged the duration from flowering to maturity and ultimately contributed to a more favourable yield. The earlier sown crop gets a more number of days

Table 4: Cumulative number of days required to attain different phenological stages as influenced by different treatments in *kharif* sunflower.

Treatment	Cumulative number of days required ot attain different phenological stages (days)											
	4 Leaf		Button		50% Flowring		Soft dough		Hard dough		Phy. Maturity	
	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022
Main Treatment												
S_1 =MW 25	14	15	44	45	57	58	66	66	78	80	87	89
S_2 =MW 30	16	15	41	43	52	55	60	64	71	76	78	85
S_3 =MW 35	14	15	43	44	55	57	65	66	77	79	85	88
SE(m) ±	0.05	0.09	0.33	0.27	0.16	0.04	0.15	0.03	0.09	0.06	0.12	0.03
CD 5%	0.20	0.33	1.30	1.07	0.64	0.15	0.40	0.13	0.33	0.25	0.45	0.13
Sub Treatment												
V_1 = SS-56	15	15	43	44	55	58	64	67	76	79	84	88
V_2 =MSFH-17	15	14	42	43	54	54	62	63	73	74	81	82
V_3 =Phule Bhaskar	15	15	43	45	56	58	65	67	77	80	87	91
SE (m) ±	0.09	0.61	0.22	0.27	0.18	0.06	0.06	0.03	0.07	0.06	0.08	0.03
CD 5%	0.26	1.51	0.67	0.82	0.54	0.19	0.19	0.10	0.22	0.20	0.24	0.10
Sub-Sub Treatment												
T_1 =Protected	15	15	42	43	54	56	64	66	77	79	86	89
T_2 = Un-protected	15	15	43	44	55	57	63	65	74	77	82	85
SE (m) ±	0.12	0.08	0.11	0.11	0.09	0.08	0.05	0.03	0.03	0.05	0.05	0.03
CD 5%	NS	NS	0.32	0.32	0.27	0.23	0.14	0.08	0.08	0.16	0.14	0.08
GM	15	15	43	44	55	56	64	**66**	75	**78**	84	**87**

for appearances of various phenophases in as than later sown crop. These finding similar with Dutta (2011), Amin *et al*., (2017), Dhillon *et al*., (2017) and Dhakar *et al.*, (2022). Ahmed *et al*., (2020) observed sunflower crop reached 50 per cent flowering in 46 to 60 days and physiological maturity in 81 to 96 days within different sowing windows.

- **Effect of varieties**

In 2021, the cultivar V_3-Phule Bhaskar recorded a significant meaner number of days to attain various phenological stages, with durations of 43, 56, 65, 77, and 87 days for button, 50 per cent flowering, soft dough, hard dough, and physiological maturity, respectively. V_1-SS-56 followed closely with durations of 43, 55, 64, 76, and 84 days, while V_2-MSFH-17 recorded slightly shorter durations of 42, 54, 62, 73, and 81 days for the corresponding stages. In 2022, similar trend persisted with the V_3-Phule Bhaskar maintained its dominance, requiring significantly more days for phenological stages with durations of 45, 58, 67, 80, and 91 days, V_1-SS-56 required 44, 58, 67, 79, and 88 days, and V_2-MSFH-17 exhibited shorter durations of 43, 54, 63, 74, and 82 days for same phenological stages (Table 4). These findings underscore the consistent pattern of V_3-Phule Bhaskar requiring more time to progress through phenological stages in both 2021 and 2022, indicating potential differences in developmental rates compared to V_1-SS-56 and V_2-MSFH-17. The prolonged durations for V_3-Phule Bhaskar may be influenced by unique genetic traits or specific responses to environmental conditions. This finding indicates that under rainfed conditions, the cultivar V_3-Phule Bhaskar exhibited significantly superior over all other cultivars.

- **Effect of treatment**

In both 2021 and 2022, the T_1-protected condition consistently recorded significantly longer mean durations for attaining various phenological stages compared to the T_2-unprotected condition. In 2021, the differences were evident across button, 50 per cent flowering, soft dough, hard dough, and physiological maturity stages, with durations of 42, 54, 64, 77, and 86 days in the T_1-protected condition and 43, 55, 63, 74, and 82 days in the T_2-unprotected condition, respectively. Similarly, in 2022, the protected condition maintained this trend, showcasing significantly higher mean durations for button, 50 per cent flowering, soft dough, hard dough, and physiological maturity stages (43, 56, 66, 79 and 89 days) compared to the T_2-unprotected condition (44, 57, 65, 77, and 85 days) (Table 4).

Conclusion

The data indicated that the under-scarcity zone, early sowing (S_1-MW 25), consistently resulted in higher plant height, increased number of leaves plant^{-1}, higher total dry matter accumulation, and longer durations to attain phenological stages compared to later sowing windows (S_2-MW 30 and S_3-MW 35). The cultivars V_3-Phule Bhaskar consistently exhibited the most favorable attributes and longer durations to reach phenological stages superior over V_1-SS-56 and V_2-MSFH-17 in scarcity conditions. The T_1-protected treatment consistently outperformed the T_2-unprotected treatment across all parameters studied, indicating the positive impact of protective measures on sunflower growth and development. The findings concluded the importance of sowing timing, cultivar selection, and protective measures for optimal sunflower growth and development, and altimatly productivity in scarcity conditions.

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