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Effect of sowing windows and variety on yield and yield components of *kharif* sunflower

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Abstract
The present field experiment was conducted during *kharif* season of 2021 and 2022 at Zonal Agricultural Research Station, Solapur to study the influences of sowing windows and variety on yield and yield components of sunflower under scarcity zone of Maharashtra. The three varieties of sunflower V_1-SS-56, V_2-MSFH-17 and V_3-Phule Bhaskar were evaluated under three sowing windows *viz.* S_1-MW25, S_2-MW30 and S_3-MW35 in T_1-protected and T_2-unprotected conditions. During experimental period, it was found that the S_1-MW25 and V_3-Phule Bhaskar cultivar in protected conditions yielded superior compared to other treatments. The result revealed that the yield and yield components *i.e.* diameter of head (17.42 cm), weight of head (119.64 g), weight of seed head^{-1} (48.34 g), number of seeds head^{-1} (899.76), seed index (48.91 gm), grain yield (1187.70 kg ha^{-1}) and stover yield (3358.03 kg ha^{-1}) during experimental period.

Keywords: *Kharif* sunflower, sowing window, variety, yield, yield components

Introduction

Sunflower (*Helianthus annuus*) is native to the Southern USA and Mexico, belonging to the Asteraceae family. The genus name, *Helianthus*, originates from the Greek words "*helios*" (sun) and "*anthos*" (flower). In ancient ceremonies, they were used as ornamental plants (Harter *et al.*, 2004) [11]. Introduced to India as an oilseed in 1969, they are known as Surajmukhi and have gained popularity due to national priorities in vegetable oil production and oilseed technology missions. It is used in production of oil and ethyl alcohol, preparation of cosmetics and pharmaceuticals, manufacturing hydrogenated oil, dye and paint, producing meal for livestock feed, growth medium for yeast (Kunduraci *et al.*, 2010) [15]. The derived meal is plentiful in protein and minerals, enhancing its nutritional value for human consumption (Jithender *et al.*, 2019) [12].

In India, the predominant cultivation of oilseeds occurs in rainfed regions, where water availability plays a pivotal role in sunflower farming. The productivity of sunflower cultivation is significantly influenced by environmental factors, including temperature, precipitation, rainfall distribution, and sowing windows (Kaleem *et al.*, 2011; Anjum *et al.*, 2012) [13, 5]. Insufficient and irregular precipitation during the growing period poses challenges for crop production in rainfed conditions (Agele *et al.*, 2003) [1]. Sunflower exhibits enhanced drought tolerance compared to sorghum (*Sorghum bicolor* L.) (Rachid *et al.*, 1993) [18], attributed to its ability to withstand water stress conditions due to a robust explorative root system. Particularly in dryland areas, sunflower efficiently extracts moisture from deeper soil depths, contributing to the crop's resilience under water stress (Meinke *et al.*, 1993) [17].

Materials and Methods

The field experiment was conducted at Zonal Agricultural Research Station, Solapur, Maharashtra, during the *kharif* seasons of 2021 and 2022. Implemented in a split-split plot design with three replications, the experiment consisted of eighteen treatment combinations, incorporating different sowing windows, varieties, and protection-unprotected measures. The main plot treatment involved three sowing windows: S_1-25th MW, S_2-30th MW, and S_3-35th MW.

Sub-plot treatment included three varieties: V_1-SS-56, V_2-MSFH-17, and V_3-Phule Bhaskar. The sub-sub treatment comprised T_1-Protected using insecticides and fungicides and T_2-Unprotected conditions. All cultivars were dibbled according to different sowing windows, maintaining a spacing of 45 cm x 20 cm.

The yield and its components, such as head diameter (cm), head weight (g), weight of seed head^{-1} (g), number of seeds head^{-1}, seed index (g), grain yield (kg ha^{-1}), and stover yield (kg ha^{-1}), were documented for five randomly selected plants from each net plot. After harvesting, which included observational plants, all plants within each net plot were harvested. The seeds were threshed, and the seed and stover yields per net plot were recorded. These values were then converted to a hectare basis by multiplying with the hectare factor.

Results and Discussion

Yield contributing characters

The study recorded various yield-contributing factors of sunflower, including head diameter, head weight, weight seeds ead^{-1}, seeds head^{-1} and 1000-grain weight, influenced by different treatments. The mean values for these parameters in 2021 and 2022 were 17.42 cm, 119.64 g, 48.34 g, 899.76 and 48.91 g, respectively.

Diameter of Head (cm)

The recorded data highlights the mean diameter of sunflower heads (cm) and its influence under different treatments throughout 2021 and 2022. The highest recorded diameter of sunflower heads plant^{-1} was significantly observed at S_1-MW 25 (18.33 cm), followed by S_3-MW 35 (17.05 cm) and S_2-MW 30 (16.88 cm) in the pooled data for 2021 and 2022. While, S_1-MW 25 showed no significant difference when compared to S_2-MW 30 and S_3-MW 35. Sunflower head diameter diminishes with delayed sowing, a trend supported by studies such as Miller *et al*. (1984) [16] who observed adverse effects from water stress during vegetative and reproductive stages. The cultivar V_3-Phule Bhaskar exhibited the highest recorded head diameter plant^{-1} (18.67 cm) significantly over V_2-MSFH-17 (17.54 cm) and V_1-SS-56 (16.05 cm) in experimental periods. This could be attributed to the genetic traits of Phule Bhaskar. The plants in protected treatment showed maximum head diameter (19.26 cm) significantly over unprotected treatment (15.57 cm).

Weight of Head (g)

The data in Table 1 illustrates the impact of different treatments on the mean head weight (cm) in 2021 and 2022. The average head weight across the experimental periods was recorded at 119.64 cm. S_1-MW 25 sown crop boasting 121.96 g head weight plant^{-1}, followed by S_3-MW 35 (118.57 g) and S_2-MW 30 (118.39 g). Delayed sowing shows a clear trend of decreasing head weight, aligning with studies by Andrade (1995) [4], Agele *et al*. (2007), Ahmed *et al*. (2015) [3], and Sharma *et al*. (2017) [19]. During the experiment, V_3-Phule Bhaskar exhibited significant higher head weight plant^{-1} at 127.17 g, outshining V_2-MSFH-17 (120.11 g) and V_1-SS-56 (111.64 g). The weight of head plant-1 was significantly higher in the protected treatment (123.47 g) compared to the unprotected treatment (115.81 g).

Weight of Seeds Head^{-1} (g)

The data presented in Table 1 depicts the influence of various treatments on the mean seed weight of the head (g). The highest mean seed weight was observed in the S_1-MW 25 sown crop (49.58 g), followed by S_3-MW 35 (48.06 g) and S_2-MW 30 (47.36 g). Ahmed *et al*. (2015) [3] reported seed head weights ranging from 50 g to 66 g in different sowing windows, emphasizing a decrease in weight with delayed sowing a finding supported by Andrade (1995) [4], Agele *et al*. (2007), Ahmed *et al*. (2015) [3], and Sharma *et al*. (2017) [19]. The V_3-Phule Bhaskar exhibited significantly the highest mean seed weight (51.27 g), followed by V_2-MSFH-17 (48.03 g) and V_1-SS-56 (45.75 g) during the experimental periods. The weight of seeds head^{-1} was notably higher (50.97 g) in the protected treatment compared to the unprotected treatment (45.71 g).

Table 1: Pooled yield components as influenced by different treatment in *kharif* sunflower (2021&2022)

Treatment	Diameter of head (cm)	Weight of head (g)	Weight of Seeds head^{-1} (g)	Number of seeds head^{-1}	1000 seed weight (g)
Main Treatment (Sowing Window)					
S_1 = MW 25	18.33	121.96	49.58	920.86	50.10
S_2 = MW 30	16.88	118.39	47.36	876.78	47.11
S_3 = MW 35	17.05	118.57	48.06	901.64	49.51
SE (m) ±	0.81	4.52	2.52	24.73	2.65
CD 5%	2.56	14.39	8.12	76.44	8.18
Sub Treatment (Cultivar)					
V_1 = SS-56	16.05	111.64	45.75	864.94	46.11
V_2 = MSFH-17	17.54	120.11	48.03	908.81	48.02
V_3 = Phule Bhaskar	18.67	127.17	51.23	925.53	52.59
SE (m) ±	0.76	2.89	1.22	14.16	1.57
CD 5%	2.34	8.46	3.57	41.32	4.57
Sub-Sub Treatment					
T_1 = Protected	19.26	123.47	50.97	936.70	51.05
T_2 = Unprotected	15.57	115.81	45.71	862.81	46.76
SE (m) ±	0.17	0.45	0.39	6.59	0.12
CD 5%	0.49	1.30	1.13	18.91	0.34
General Mean	17.42	119.64	48.34	899.76	48.91

Number of Seeds Head^{-1}

During the experiment, the mean number of seeds head^{-1} was 899.76, as detailed in Table 1. The highest mean number of seeds head^{-1} was observed in the S_1-MW 25 sown crop (920.86), followed by S_3-MW 35 (901.64) and S_2-MW 30 (876.78). Additionally, during the experiment, the V_3-Phule Bhaskar displayed significantly the highest mean number of seeds head^{-1} (925.53), followed by V_2-MSFH-17 (908.81) and V_1-SS-56 (864.94). The protected treatment was significantly superior (936.70) over unprotected treatment (862.81) for number of seeds head^{-1}.

Seed Index
The analysis of the data in Table 1 reveals notable variations in the mean seed index influenced by different treatments during the 2021 and 2022 experiments. With an overall mean seed index of 48.91 g, the S_1-MW25 sown crop exhibited the highest value at 50.10 g, followed by S_3-MW35 (49.51 g) and S_2-MW30 (47.11 g). These findings align with the seed index range reported by Demir (2019) [6] of 38.95 g to 50.13 g. Notably, the results indicate a consistent trend of decreasing seed index with delayed sowing, in accordance with the observations made by Andrade (1995) [4], Agele *et al*. (2003) [1], and Ahmed *et al*. (2015) [3]. Cultivar analysis revealed that V_3-Phule Bhaskar had significantly the highest seed index (52.59 g), followed by V_2-MSFH-17 (48.02 g) and V_1-SS-56 (46.11 g) during the experiment. The protected treatment was significantly superior (51.05 g) over unprotected treatment (46.76 g) for number of seeds index.

Yield Studies
Grain Yield (kg ha^{-1})
The data regarding mean grain yield (kg ha^{-1}) influenced by different treatments in 2021 and 2022 is detailed in Table 2. The overall pooled grain yield was 1187.70 kg ha^{-1}, with the highest yield observed in the S_1-MW 25 sown crop (1249.62 kg ha^{-1}), followed by S_2-MW 30 (1158.93 kg ha^{-1}) and S_3-MW 35 (1154.52 kg ha^{-1}). These findings align with previous reports by Sur and Sharma (1999) [21], Agele *et al*. (2003) [1], Dutta (2011) [9], Dhanasekar *et al*. (2012) [7], Kawade *et al*. (2018) [14], and Demir (2019) [6], indicating a decrease in grain yield with delayed sowing dates. The early sowing at S_1-MW25 provides ample time for biological and reproductive development, resulting in higher grain yield, possibly due to consistent moisture availability throughout the crop's life span. Late-sown crops displayed characteristics such as smaller plants, heads, a reduced number of seeds, lower 100-seed weight, and early flowering and maturity, resulting in diminished seed yield compared to early sowing. These observations are consistent with findings by Agrawal *et al*. (2002) [2]. Singh *et al*. (1997) [20] reported that delayed sowing had an adverse impact on crop growth, leading to a shortened reproductive period and a subsequent decrease in yield. Tomar *et al*. (1997) [22] documented that late-sown crops experienced moisture deficit in the later stages of the growing season, coinciding with flowering and seed setting, which had a detrimental effect on overall yield. Among cultivars, V_3-Phule Bhaskar exhibited significantly higher grain yield (1309.43 kg ha^{-1}) compared to V_2-MSFH-17 (1197.73 kg ha^{-1}) and V_1-SS-56 (1056.00 kg ha^{-1}), suggesting its sustainability in scarcity zones, potentially due to its longer lifespan and better adaptation to moisture conditions during reproductive stages. The grain yield in protected treatment was significantly superior (1263.18 kg ha^{-1}) over unprotected treatment (1112.22 kg ha^{-1}).

Stover Yield (kg ha^{-1})
The data in Table 2 illustrates the impact of various treatments on mean stover yield (kg ha^{-1}) for the years 2021 and 2022. The overall stover yield averaged 3358.03 kg ha^{-1}. Notably, the crop sown in S_1-MW 25 exhibited the highest stover yield at 3631.37 kg ha^{-1}, followed by S_3-MW 35 (3306.81 kg ha^{-1}) and S_2-MW 30 (3135.91 kg ha^{-1}). Sur and Sharma (1999) [21] reported stover yield ranging from 3563 kg ha^{-1} to 3970 kg ha^{-1} for different sowing dates, supporting the observation that delaying sowing leads to decreased stover yield. The findings align with Andrade (1995) [4], Agele *et al.* (2003) [1], Dutta (2011) [9], and Kawade *et al.* (2018) [14], indicating a consensus that stover yield diminishes with delayed sowing. Dhillon *et al.* (2018) [8] emphasized that delayed sowing significantly reduces sunflower biological yield, attributed to diminished photosynthetic parameters and a shortened crop duration. In terms of cultivars, V_3-Phule Bhaskar exhibited significantly higher stover yield (3736.79 kg ha^{-1}) compared to V_2-MSFH-17 (3415.21 kg ha^{-1}) and V_1-SS-56 (2922.08 kg ha^{-1}). This suggests the superior sustainability of the Phule Bhaskar variety, possibly due to its longer life span and resilience to moisture stress during reproductive stages as compared to V_2-MSFH-17 and V_1-SS-56. The protected treatment was significantly superior (3655.33 kg ha^{-1}) over unprotected treatment (3060.72 kg ha^{-1}) for stover yield.

Table 2: Mean grain yield and stover yield as influenced by different treatments in *kharif* sunflower

Treatment	Grain Yield (kg ha^{-1})			Stover Yield (kg ha^{-1})		
	2021	2022	Pooled	2021	2022	Pooled
Main Treatment (Sowing Window)						
S_1 = MW 25	1301.49	1197.79	1249.62	3767.41	3495.32	3631.37
S_2 = MW 30	928.99	1388.87	1158.93	2526.02	3745.81	3135.91
S_3 = MW 35	1156.78	1152.25	1154.52	3301.28	3312.34	3306.81
SE (m) ±	42.54	35.13	38.84	10.89	10.17	12.91
CD 5%	166.82	137.71	152.26	42.78	39.94	42.10
Sub Treatment (Cultivar)						
V_1 = SS-56	997.60	1114.40	1056.00	2742.94	3101.22	2922.08
V_2 = MSFH-17	1156.64	1238.81	1197.73	3317.94	3512.49	3415.21
V_3 = Phule Bhaskar	1233.15	1385.70	1309.43	3533.82	3939.77	3736.79
SE (m) ±	28.44	25.72	27.08	06.21	11.07	10.99
CD 5%	87.46	79.38	83.42	19.14	34.12	32.09
Sub-Sub Treatment						
T_1 = Protected	1208.56	1317.8	1263.18	3502.08	3808.59	3655.33
T_2 = Unprotected	1049.64	1174.8	1112.22	2894.39	3227.06	3060.72
SE (m) ±	24.02	29.22	26.62	5.99	3.57	6.04
CD 5%	71.35	86.61	78.98	17.81	10549	17.32
General Mean	1129.10	1246.30	1187.70	3198.23	3517.82	3358.03

Conclusion
The timing of sowing plays a crucial role in the cultivation of sunflower in rainfed regions of India. Early sowing (S_1-MW25) consistently resulted in higher yield and yield contributing characteristics as evidenced by larger head diameters, heavier heads, increased seed weight head^{-1}, higher seed numbers head^{-1}, higher seed index, grain and stover yield. This underscores the importance of timely planting for optimal sunflower production, providing ample time for biological and reproductive development and ensuring consistent moisture availability throughout the crop's lifespan. The choice of cultivar significantly influenced yield-contributing factors, with V_3-Phule Bhaskar consistently outperforming V_2-MSFH-17 and V_1-SS-56 across various parameters. The superior performance of V_3-Phule Bhaskar suggests its suitability for cultivation in diverse environmental conditions, potentially attributed to its genetic traits, longer lifespan, and better adaptation to moisture stress. The protective treatments using agrochemicals effectively enhance yield by controlling harmful insects.

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