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Staggered Sowing and Manuring Effects on Hybrid Sunflower (*Helianthus annuus*) during *Rabi* Season in Coastal Bengal

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Field experiments were conducted during *Rabi* seasons of 2018-19 and 2019-20 at Regional Research Station (CSZ), BCKV, Kakdwip, South 24-Parganas, West Bengal to assess the variation in growth and yield determining traits of hybrid sunflower (cv. Sunbred 275) under staggered sowing and manuring practices. The field trial was arranged in a split-plot design with four sowing dates (S_1 = November 30, S_2 = December 07, S_3 = December 14 and S_4 = December 21) in main plots and three manuring practices (M_1 = 100% RDF *i.e.*, 80:40:40 kg N:P_2O_5:K_2O kg ha^{-1}), M_2 = 75% RDF + vermicompost @ 5 t ha^{-1} and M_3 = 75% RDF + farm yard manure @ 10 t ha^{-1}) assigned to the sub-plots, each replicated thrice. Growth attributes, yield components and seed yield (2.14 t ha^{-1}) of sunflower were found to be significantly higher in early-sown crop (November 30). Subsequent delay in seed sowing beyond November 30 caused poor vegetative and reproductive growth of crops and thereby resulted in poor growth attributes, yield components, seed oil content, seed yield and stover yield of test crop. Application of 100 % RDF gave significantly higher growth attributes, yield components, seed oil content (38.6 %), seed yield (1.91 t ha^{-1}), stover yield (6.07 t ha^{-1}) and economic benefit (B:C ratio of 1.62) of sunflower. However, the treatment 75% RDF + 5.0 t vermicompost ha^{-1} gave at par results for seed oil content (39.7%), seed yield (1.86 t ha^{-1}) and stover yield (5.96 t ha^{-1}). Seed sowing on November 30 with 100% RDF may be recommended for maximizing sunflower production during *Rabi* in coastal West Bengal. However, considering the need to reduce fertilizer consumption and maintain soil health, the treatment comprising 75% RDF + 5.0 t vermicompost ha^{-1} would be beneficial for sustainable sunflower cultivation in the region.

(***Key words:*** *Economics, Hybrid sunflower, Manuring, Oil content, Staggered sowing, Yield)*

The cultivation of sunflower crop is mostly restricted to irrigated areas in Bengal, particularly during *Rabi* season. In recent times, this crop has been included in various crop-intensification programs in non-traditional areas mainly dominated by rice-fallow system (Alipatra *et al.*, 2019a). As a result, the area under sunflower in the state has increased by many folds during past decade reaching at 7258 hectares in 2020-21 and consequently, 8570 tonnes seed was produced with a low average productivity of 1181 kg ha^{-1}(GoWB, 2021).

In coastal Bengal, there is limited scope for crop cultivation in post-rainy season primarily due to irrigation water and soil salinity stresses. Moreover, the late and untimely harvest of *Kharif* paddy further aggravates the problem and provides a small window for *Rabi* crop cultivation (Samanta *et al.*, 2022). In case of extreme delay in paddy harvest, farmers are often compelled to go for spring crop cultivation instead of *Rabi* crop. Under such delayed conditions, sunflower can be grown in *Rabi* season with a little deviation of sowing time assuming a meagre yield loss. Farmers of the coastal region have already adopted *Rabi* sunflower cultivation due to its early maturity and photo-insensitivity (Kundu *et al.,* 2023), but very often they fail to sow the seeds at an optimum time. Late sowing of sunflower may also cause yield reduction due to moisture stress (Alipatra *et al.,* 2019a), but the extent of reduction has not been clearly estimated for saline tracts. Irrespective of sowing time, sunflower growers in this region always go for blanket application of fertilizers. This ultimately leads to unexpected growth performance of crop, resulting in poor seed yield. Although Alipatra *et al.* (2019a) proved the beneficial effect of integrated nutrient management (INM) for sunflower cultivation in alluvial soils, no such evidence is available so far for saline soils of coastal Bengal.

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Hence, a suitable agronomic package for sunflower cultivation having the synchrony between sowing date and manuring is urgently needed for coastal saline tracts. Against this backdrop, the present study was focused on the growth and variation in yield and yield attributes of hybrid sunflower due to staggered sowing and manuring practices in saline tracts of Kakdwip (West Bengal).

MATERIALS AND METHODS

Field experiments were conducted during *Rabi* seasons of 2018-19 and 2019-20 at the Regional Research Station (Coastal Saline Zone) under Bidhan Chandra Krishi Viswavidyalaya, Akshaynagar, Kakdwip, South 24-Parganas, West Bengal (situated at 22°40' N latitude, 88°18' E longitude and 7 m above mean sea level). The objective of the present study was to assess the variation in growth and yield determining traits of hybrid sunflower under staggered sowing and manuring practices in coastal Bengal. The experimental soil (0-30 cm layer) was clay in texture with $pH_{1:2.5}$ of 5.90, organic carbon of 0.62%, $EC_{1:2.5}$ of 1.6 dS m^{-1} (low salinity), available N of 163 kg ha^{-1}, available P_2O_5 of 94.5 kg ha^{-1} and available K_2O of 320.5 kg ha^{-1}.

The field trial was arranged in a split-plot design with four sowing dates in the main plots and three manuring practices assigned to the sub-plots, each replicated thrice. The area of each plot was 20 m^2 (5 m × 4 m). In this study, seeds were sown four times at weekly intervals (S_1 = Nov. 30, S_2 = Dec. 07, S_3 = Dec. 14 and S_4 = Dec. 21), while the three manuring practices were M_1 = 100% Recommended dose of fertilizer (RDF) *i.e.*, 80:40:40 kg $N:P_2O_5:K_2O$ kg ha^{-1}), M_2 = 75% RDF + vermicompost (VM) @ 5 t ha^{-1} and M_3 = 75% RDF + farm yard manure (FYM) @ 10 t ha^{-1}. The sunflower cultivar 'Sunbred 275' was grown as a test crop under irrigated medium land situation with a good drainage facility. Sunbred 275 is a hybrid variety having a duration of 95-105 days, yield potential of 1.8-2.0 t ha^{-1} and is suitable for all types of soil and agro-climatic conditions. Seeds were dibbled @ 6 kg ha^{-1} under line sowing at 60 cm × 30 cm spacing on four pre-determined dates. Excess plants were thinned out at 30 days after sowing (DAS) to maintain the optimum plant population. Fertilizer NPK were provided to crop with urea, single super phosphate (SSP) and muriate of potash (MOP) at pre-determined rates. At each fertilizer level, the half dose of N along with a full dose of P and K were supplied as basal during final land preparation (just before seed sowing). The remaining half dose of N was top-dressed at 30 DAS. Both VC (1.4% N, 0.95% P_2O_5 and 1.15% K_2O) and FYM (0.55% N, 0.25% P_2O_5 and 0.60% K_2O) were surface broadcasted during final land preparation (as basal) at 7 days before sowing. One light irrigation was provided just after sowing to facilitate germination. Additional two irrigations were given at the flower initiation stage (60 DAS) and grain filling stage (80 DAS). Two hand weedings were done at 25 and 50 DAS to keep the plots weed-free and to promote crop growth. The crop was harvested when the backs of flower heads turned lemon yellow or yellowish brown near the stalk, discs started drying and seeds became blackish and fully ripened.

In each plot, 5 randomly selected plants from destructive sampling (4 m long row) were used to record plant height and number of leaves per plant at different time intervals. Characteristics of the matured capitulum (diameter, number of seeds and weight) were recorded at maturity (115 DAS). Plants were cut at the base after attaining harvest maturity (115 DAS). Plot-wise matured capitula and stover were sun-dried for 7 days and then seeds were separated by beating with sticks to estimate yield. For the determination of seed oil content, standard procedure was followed (AOAC, 2005). The economic assessment in terms of gross return, net return and benefit-cost ratio of hybrid sunflower cultivation was worked out based on the prevailing market price.

Various thermal indices were used to determine the requirement of heat units to attain different growth stages of sunflower crop. Growing degree-days (GDD), photo-thermal unit (PTU), photo-thermal index (PTI) and heat-use efficiency (HUE) were calculated as per the following formula suggested by Singh *et al.* (2014).

$$GDD = \sum_{i=1}^{n} \frac{T_{max} + T_{min}}{2} - T_b \quad ...(1)$$

where, T_{max} = Daily maximum temperature, T_{min} = Daily minimum temperature, T_b = Base temperature (10°C) and n = Number of days required to attain a specific phenological stage.

$$PTU \text{ (Degree-days hours)} = GDD \times \text{Day length} \quad ...(2)$$

$$\text{PTI (Degree-days day}^{-1}) = \frac{\text{GDD}}{\text{Growth days}} \quad ...(3)$$

$$\text{HUE (kg ha}^{-1}\text{ degree-days}^{-1}) = \frac{\text{Seed yield (kg ha}^{-1})}{\text{GDD}} \quad ...(4)$$

The experimental data were analysed by the analysis of variance (ANOVA) using the STAR software version 2.0.1 (IRRI, 2014). The significant difference between the treatment means was tested by Duncan's multiple range test (Duncan, 1955) at $p \leq 0.05$ when the F-test was significant at $p \leq 0.05$.

RESULTS AND DISCUSSION

Growth attributes of hybrid sunflower

In both years, plant height was found to increase over time and it was maximum at 90 DAS, irrespective of sowing date and manuring practice (Table 1). Irrespective of manuring practices, early sown crop (Nov. 30) attained maximum height at 90 DAS (142.4 and 138.5 cm in *Rabi* 2018-19 and 2019-20, respectively). Delayed sowing resulted in poor height of crop and it was significantly lowest (101.1 and 110.0 cm in *Rabi* 2018-19 and 2019-20, respectively) in extremely late sown crop (Dec. 21). Pooled data (Table 1) also holds the same trend, representing the highest plant height (140.5 cm) in early sown crop (Nov. 30) and lowest (105.6 cm) in late sown crop (Dec. 21). Early or timely-sown crop exhibited better vegetative growth, as the crop experienced less or no environmental stress at all and thereby enabled the plants to utilize resources (light, nutrient and others) more effectively and efficiently. On the contrary, the late-sown sunflower might have experienced the adverse effect of low temperature during the vegetative stage, thereby exhibiting stunted growth (Rana *et al.,* 2020). Manuring practice did not bring any significant differences in plant height on different dates of observation and this holds true for both year-wise and pooled data. However, it was higher with the crop receiving 100% RDF (133.2 and 126.9 cm in *Rabi* 2018-19 and 2019-20, respectively). Pooled data (Table 1) shows that crops receiving M_1 and M_3 treatments gave higher (131.1 cm) and lower plant heights (126.2 cm), respectively. Leaf production in sunflower plants continued up to 60 DAS, and then declined due to the natural process of senescence (Table 1). Sunflower plant produced a significantly higher number of leaves plant^{-1} (23.6 and 25.5 at 65 DAS in *Rabi* 2018-19 and 2019-20, respectively) when sown on Nov. 30. But leaf production was hampered significantly as sowing was delayed beyond Nov. 30; and extremely late sown crop (Dec. 21) produced lowest number of leaves plant^{-1} (16.6 and 16.3 at 65 DAS in *Rabi* 2018-19 and 2019-20, respectively), irrespective of manuring practices. Pooled data (Table 1) also reveals that early sown crop produced the maximum number of leaves plant^{-1} (17.7) than that of late sown crop (15.4). Uncongenial low temperatures exerted a negative impact on the overall vegetative growth of sunflower crop (Rana *et al.,* 2020), which was clearly reflected as poor canopy development with a smaller number of leaves. There was a lack of significant variation in the leaf number of sunflower plants due to manuring practices. However, application of 100% RDF resulted higher number of leaves per plant (20.2 and 19.4 at 65 DAS in *Rabi* 2018-19 and 2019-20, respectively), irrespective of sowing time. Pooled data (Table 1) shows that crops receiving M_1 and M_3 treatments gave higher (16.7) and lower number of leaves plant^{-1} (16.1), respectively. Under performance of sunflower crop with the combined use of chemical fertilizers and organic manures (VC/FYM) was noted, which might be due to reduced nutrient availability immediately after their application in the field; hence, nutrient uptake by sunflower plants was poor under INM practices. Being a deep-rooted crop, the sunflower crop might have failed to take up nutrients that were released from organic sources, as the nutrients immediately after their release from VC/FYM remain in the upper soil layer (Banerjee *et al.,* 2014). This was clearly reflected by shorter plants with less number of leaves under INM practices. In the present study, the interaction effects were found non-significant for both the above growth attributes of hybrid sunflower.

Yield components and seed oil content of hybrid sunflower

The change in sowing dates brought about significant variation in yield components of the tested sunflower hybrid namely capitulum diameter, number of seeds capitulum^{-1}, seed weight capitulum^{-1}, capitulum weight and 100-seed weight (Table 2). All the measured yield components were found to be significantly higher in early sown crop (18.5 and 16.2 cm capitulum diameter

in *Rabi* 2018-19 and 2019-20, respectively; 912 and 885 seeds capitulum^{-1} in *Rabi* 2018-19 and 2019-20, respectively; 50.0 and 39.9g seed weight capitulum^{-1} in *Rabi* 2018-19 and 2019-20, respectively; 290.8 and 271.1g capitulum weight in *Rabi* 2018-19 and 2019-20, respectively; 61.3 and 55.5g 100-seed weight in *Rabi* 2018-19 and 2019-20, respectively). Pooled data (Table 2) also represents higher values of all the above-mentioned yield components in the case of early sown crop (Nov. 30). The poorer yield components were recorded in delayed sowing (Dec. 21), which might be due to adverse weather conditions. High temperature coupled with occasional rain exerted a negative impact on the reproductive stages of crop growth (Alipatra *et al.,* 2019b; Rana *et al.,* 2020). Hence, lower amounts of photosynthates might have accumulated in the seeds of late-sown crops. However, the variation in seed oil content was non-significant due to changes in the sowing time of the sunflower crop in both the years.

All the measured yield components of tested sunflower hybrid were also least affected or non-significantly affected by different manuring practices employed in the present study for both the years (Table 2), except in two instances where the variation was significant for number of seeds capitulum^{-1} and seed weight capitulum^{-1} in *Rabi* 2018-19 as well as in pooled data. Chemical fertilization (100% RDF) resulted in significantly higher number of seeds capitulum^{-1} (839) and seed weight capitulum^{-1} (47.5g) in *Rabi* 2018-19 than INM practices (75% RDF + VC/FYM). Pooled data (Table 2) reveals that M_1 treatments gave a significantly higher number of seeds capitulum^{-1} (819) and seed weight capitulum^{-1} (41.5g); being statistically at par with M_2 treatment (815 seeds capitulum^{-1} and 40.9 g of seed weight capitulum^{-1}). The use of organic amendments namely VC and FYM (in conjunction with chemical fertilizer) failed to show a greater impact on yield components. By the time organic manures get fully decomposed and release nutrients present in them, plants might have completed the vegetative growth and thereby failed to fulfil the demand due to the delayed availability of nutrients from organic sources (Moitra *et al.,* 2012). However, the variation in seed oil content was non-significant due to changes in manuring practices during both the years of study. This result suggests that the integration of organic manures with chemical fertilizers was capable of maintaining the seed oil content of the sunflower crop, probably due to better availability of macro and micronutrients, sulphur in particular (Moitra *et al.,* 2012; Alipatra *et al.,* 2019b). In the present study, the interaction effect failed to record any significant variation in yield components and seed oil content in tested hybrid sunflower.

Yield of hybrid sunflower and production economics

Both seed and stover yield of tested hybrid sunflower were significantly affected by the sowing date and this holds true for both the years of study (Table 3). The significantly higher seed yield (2.21 and 2.07 t ha^{-1} in *Rabi* 2018-19 and 2019-20, respectively) and stover yield (7.23 and 6.67 t ha^{-1} in *Rabi* 2018-19 and 2019-20, respectively) were obtained from early sown crop (Nov. 30), while yields were poor due to late sowing. This holds true for pooled data also (Table 3), which represents that early sown crops gave significantly higher seed (2.14 t ha^{-1}) and stover yields (6.95 t ha^{-1}) of sunflower. Seed yields always exhibit a positive correlation with the yield contributing traits. Hence, in the present study also an improvement in yield components of tested hybrid sunflower crop due to early sowing resulted in a significant increase in the ultimate seed and stover yield. On the contrary, an exposure of sunflower crop to dry season, as a result of delayed sowing, was expected to exert an ill effect on account of low moisture availability in crop fields. This could be further aggravated by less availability of nutrients both from organic and inorganic sources, as water and nutrient complement each other to become available for crop uptake (Moitra *et al.,* 2012).

Manuring practices brought about non-significant variation in seed and stover yields, except for seed yield in *Rabi* 2018-19 and also in pooled data where the variation was significant (Table 3). Despite the above facts, chemical fertilization proved its superiority over INM practices (75% RDF + VC/FYM) in bringing higher productivity of sunflower hybrid both in terms of seed and stover yield. Pooled data (Table 3) shows that the M_1 treatment produced maximum seed yield (1.91 t ha^{-1}); being statistically at par with M_2 treatment (1.86 t ha^{-1}). However, the variation in stover yield due to manuring treatments was non-significant. This increase might be due to the steady and increased availability of

Table 1. *Effect of sowing date and manuring on growth indicators of hybrid sunflower (cv. Sunbred 275) during Rabi season*

Treatments	Plant height (cm)						Number of leaves plant^{-1}					
	2018-19			2019-20			2018-19			2019-20		
	40 DAS	65 DAS	90 DAS	40 DAS	65 DAS	90 DAS	40 DAS	65 DAS	90 DAS	40 DAS	65 DAS	90 DAS
Sowing date												
S_1 - Nov. 30	27.3a	74.6a	142.4a	41.6a	111.3a	138.5a	14.4a	23.6a	21.0a	20.4a	25.5a	14.4a
S_2- Dec. 07	25.9a	69.0a	140.3a	39.3a	93.8b	135.5a	13.4a	21.1b	19.0b	17.7b	19.2b	13.9ba
S_3- Dec. 14	19.0b	54.5b	138.2a	30.3b	85.5c	115.4b	11.3b	18.6c	18.7b	16.5cb	17.2cb	13.2bc
S_4- Dec. 21	16.3b	50.6b	101.1b	18.7c	84.6c	110.0b	11.2b	16.6d	18.1b	14.9c	16.3c	12.6c
Manuring												
M_1- 100% RDF	22.5a	62.9a	133.2a	32.9a	95.1a	126.9a	12.8a	20.2a	19.6a	18.1a	19.4a	13.7a
M_2- 75% RDF + VC @ 5 t ha^{-1}	22.4a	62.4a	129.6a	32.4a	93.6a	123.9a	12.7a	20.0a	19.2a	17.1a	19.2a	13.5a
M_3- 75% RDF + FYM @ 10 t ha^{-1}	21.5a	61.2a	128.7a	32.2a	92.8a	123.7a	12.3a	19.7a	18.8a	17.0a	18.5a	13.4a
	Pooled						Pooled					
	40 DAS		65 DAS		90 DAS		40 DAS		65 DAS		90 DAS	
S_1	34.5a		93.0a		140.5a		17.4a		24.6a		17.7a	
S_2	32.6a		81.4b		137.9a		15.6b		20.2b		16.5ba	
S_3	24.7b		70.0c		126.8b		13.9cb		17.9cb		16.0bc	
S_4	17.5c		67.6c		105.6b		13.1c		16.5c		15.4c	
M_1	27.7a		79.0a		130.1a		15.5a		19.8a		16.7a	
M_2	27.4a		78.0a		126.8a		14.9a		19.6a		16.4a	
M_3	26.9a		77.0a		126.2a		14.7a		19.1a		16.1a	

DAS, Days after sowing; RDF, Recommended dose of fertilizer; VC, Vermicompost; FYM, Farm yard manure
In a column, means followed by common letter are not significantly different at 5% level by Duncan's Multiple Range Test (DMRT)

Table 2. *Effect of sowing date and manuring on yield components and oil content of hybrid sunflower (cv. Sunbred 275) during rabi season*

Treatments	Capitulum diameter (cm)		No. of seeds capitulum^{-1}		Seed weight capitulum^{-1} (g)		Capitulum weight (g)		100-seed weight (g)		Oil content (%)	
	2018-19	2019-20	2018-19	2019-20	2018-19	2019-20	2018-19	2019-20	2018-19	2019-20	2018-19	2019-20
Sowing date												
S_1 - Nov. 30	18.5a	16.2a	912a	885a	50.0a	39.9a	290.8a	271.3a	61.3a	55.5a	39.0a	41.1a
S_2- Dec. 07	18.2a	15.9ba	862a	847a	48.8ba	36.1ba	273.8b	251.2ba	58.2ba	42.0b	38.7a	40.7a
S_3- Dec. 14	17.9a	15.8ba	790b	810a	46.5b	33.8bc	257.3c	215.0bc	54.9bc	40.7b	38.2a	40.1a
S_4- Dec. 21	14.8b	14.6b	721c	672b	39.1c	30.2c	223.3d	185.0c	51.3c	40.6b	37.0a	38.2a
Manuring												
M_1- 100% RDF	17.4a	16.1a	839a	798a	47.5a	35.5a	263.8a	231.3a	57.5a	45.1a	36.9a	40.3a
M_2- 75% RDF + VC @ 5 t ha^{-1}	17.4a	15.6a	833ba	796a	47.0a	34.8a	263.1a	230.5a	57.2a	45.0a	39.4a	40.0a
M_3- 75% RDF + FYM @ 10 t ha^{-1}	17.2a	15.1a	790b	741b	43.8b	34.7a	257.0a	230.0a	54.7a	44.0a	38.4a	39.7a
	Pooled		Pooled		Pooled		Pooled		Pooled		Pooled	
S_1	17.4a		899a		45.0a		281.1a		58.4a		40.1a	
S_2	17.1a		855a		42.5ba		262.5ba		50.1b		39.7a	
S_3	16.9a		800a		40.2b		236.2c		47.8b		39.2a	
S_4	14.7a		697b		34.7c		204.2d		46.0b		37.6a	
M_1	16.8a		819a		41.5a		247.6a		51.3a		38.6a	
M_2	16.5a		815ba		40.9a		246.8a		51.1a		39.7a	
M_3	16.2a		766b		40.9a		243.5a		49.4a		39.1a	

RDF, Recommended dose of fertilizer; VC, Vermicompost; FYM, Farm yard manure

In a column, means followed by common letter are not significantly different at 5% level by Duncan's Multiple Range Test (DMRT)

nutrients from inorganic sources (Urea, SSP and MOP) that had resulted in increased uptake of nutrients by plants and finally augmented the seed and stover yields (Moitra *et al.,* 2012). Crop yield was below the expected level under INM practices because the crop might have received nutrients quite less than their requirement, which corresponds to poor yield attributing traits. Slow decomposition of organic manures, followed by poor nutrient availability might be the reason for the under-performance of sunflower crop in both the years (Banerjee *et al.,* 2014).

The economic benefit of hybrid sunflower cultivation was found to vary with studied factors namely sowing date and manuring practices in both the years (Table 3). Irrespective of manuring practices, the maximum gross return (INR 84272 and 78921 ha^{-1} in *Rabi* 2018-19 and 2019-20, respectively), net return (INR 34232 and 28714 ha^{-1} in *Rabi* 2018-19 and 2019-20, respectively) and B:C ratio (1.68 and 1.57 in *Rabi* 2018-19 and 2019-20, respectively) were obtained with early sown crop (Nov. 30). Pooled data (Table 3) also depicts that early sown crop gave higher gross return (INR 81597 ha^{-1}), net return (INR 31473 ha^{-1}) and B:C ratio (1.63) than the crops sown late. Higher yield of the early-sown crop was instrumental in getting higher economic gain in both the years. Based on the 2-year field experiments, 100 % RDF gave significantly higher economic benefit of sunflower production system in terms of gross return (INR 72195 and 73399 ha^{-1} in Rabi 2018-19 and 2019-20, respectively), net return (INR 27733 and 27771 ha^{-1} in *Rabi* 2018-19 and 2019-20, respectively) and B:C ratio (1.62 and 1.61 in *Rabi* 2018-19 and 2019-20, respectively), closely followed by the treatment 75% RDF + 5.0 t vermicompost ha^{-1}. Pooled data shows that M_1 treatment gave higher gross return (INR 72797 ha^{-1}), net return (INR 27752 ha^{-1}) and B:C ratio (1.62) than any other INM practices. Lower yield of the test crop under INM practices was responsible for less economic gain.

Thermal requirement for attaining different phenophases

During both the years of study, staggered sowing of sunflower crop gave a clear idea about how the thermal requirement for attaining a specific growth stage changes with the change in sowing date (Table 4). The GDD calculated for different phenophases showed that any delay in seed sowing sought more requirement of GDD to attain knee-high, budding, flowering and maturity stages, and this holds true for year-wise and pooled data. On the contrary, the early-sown crop required less GDD (1295 and 1273 degree-days in *Rabi* 2018-19 and 2019-20, respectively) to attain maturity than the late-sown crop, with a mean value of 1284 degree-days (Table 4). The trend of photo-thermal unit (PTU) and photo-thermal index (PTI) requirements to attain various phenophases was exactly the same as that of GDD. The early sown crop required less PTU (15549 and 15285 degree-days hour in *Rabi* 2018-19 and 2019-20, respectively) and PTI (11.27 and 11.08 degree-days day^{-1} in *Rabi* 2018-19 and 2019-20, respectively) to attain maturity, with a mean value of 15417 degree-days hour (PTU) and 11.17 degree-days day^{-1} (PTI), and the values were quite less as compared to those of late-sown crops. Summarily, all the above three thermal indices (GDD, PTU and PTI) increased with delay in sowing following the trend Nov. 30 < Dec. 07 < Dec. 14 < Dec. 21. The above finding clearly indicates that the early-sown crop utilized less heat units to reach at a specific growth stage, while late-sown crops exploited more heat units, irrespective of growth stages (Rana *et al.,* 2020). Quite expectedly, just the opposite trend was observed in the case of heat-use efficiency (HUE). The heat-use efficiency (HUE) was more in case of early-sown crop (1.71 and 1.63 kg ha^{-1} degree-days in *Rabi* 2018-19 and 2019-20, respectively) and it decreased with delay in sowing following the trend Nov. 30 > Dec. 07 > Dec. 14 > Dec. 21 (Table 4), as depicted in year-wise and mean data. This result undoubtedly suggests that the early-sown crop used heat more efficiently than the late-sown crops (Singh *et al.,* 2014; Devi *et al.,* 2019).

CONCLUSION

In summary, it was concluded that both the sowing date and manuring practices are crucial for the successful cultivation of sunflower crop. Views extrapolated from the results revealed that seed sowing on November 30 with the application of chemical fertilization (100% RDF *i.e.* 80:40:40 kg $N:P_2O_5:K_2O$ kg ha^{-1}) would be beneficial for productive and profitable sunflower production during *Rabi* season in coastal Bengal. However, to promote sustainable sunflower cultivation

Table 3. *Effect of sowing date and manuring on yield and economics of hybrid sunflower (cv. Sunbred 275) during rabi season*

Treatments	Seed yield (t ha^{-1})		Stover yield (t ha^{-1})		Cost of cultivation (INR ha^{-1})		Gross return (INR ha^{-1})		Net return (INR ha^{-1})		Benefit: cost ratio	
	2018-19	2019-20	2018-19	2019-20	2018-19	2019-20	2018-19	2019-20	2018-19	2019-20	2018-19	2019-20
Sowing date												
S_1 - Nov. 30	2.21a	2.07a	7.23a	6.67a	50041a	50207a	84273a	78921a	34232a	28714a	1.68a	1.57a
S_2- Dec. 07	1.98b	1.92ba	7.02a	5.61ba	50041a	50207a	75498b	73283ba	25457b	23076b	1.51b	1.46b
S_3- Dec. 14	1.83b	1.75b	5.96b	5.08b	50041a	50207a	69869b	66595b	19828b	16388c	1.40cb	1.33c
S_4- Dec. 21	1.71c	1.69b	5.51b	4.72b	50041a	50207a	65325c	64484b	15284c	14277dc	1.31dc	1.28dc
Manuring												
M_1- 100% RDF	1.89a	1.93a	6.46a	5.67a	44462c	45628c	72195a	73399a	27733a	27771a	1.62a	1.61a
M_2- 75% RDF + VC @ 5 t ha^{-1}	1.83a	1.89a	6.46a	5.46a	49457b	50623b	69729a	71973a	20272b	21350b	1.41b	1.42b
M_3- 75% RDF + FYM @ 10 t ha^{-1}	1.56b	1.76a	6.36a	5.43a	53203a	54370a	59347b	67090a	6144c	12720b	1.12c	1.23c
	Pooled		Pooled		Pooled		Pooled		Pooled		Pooled	
S_1	2.14a		6.95a		50124a		81597a		31473a		1.63a	
S_2	1.95b		6.32a		50124a		74391b		24267b		1.49b	
S_3	1.79b		5.52b		50124a		68232b		18108b		1.37cb	
S_4	1.70c		5.12b		50124a		64905c		14781c		1.30dc	
M_1	1.91a		6.07a		45045c		72797a		27752a		1.62a	
M_2	1.86a		5.96a		50040b		70851a		20811b		1.42b	
M_3	1.66b		5.90a		53787a		63219b		9432c		1.18c	

RDF, Recommended dose of fertilizer; VC, Vermicompost; FYM, Farm yard manure

In a column, means followed by common letter are not significantly different at 5% level by Duncan's Multiple Range Test (DMRT)

Table 4. *Growing degree-days (GDD), photothermal unit (PTU), photo-thermal index (PTI) and heat-use efficiency (HTU) required for some specific phenophases in hybrid sunflower (cv. Sunbred 275) under different sowing days during Rabi season*

Sowing dates	GDD (degree-days)				PTU (degree-days hours)				PTI (degree-days day^{-1})				HUE (kg ha^{-1} degree-days^{-1})			
	40 DAS	55 DAS	75 DAS	115 DAS	40 DAS	55 DAS	75 DAS	115 DAS	40 DAS	55 DAS	75 DAS	115 DAS	40 DAS	55 DAS	75 DAS	115 DAS
2018-19																
Nov. 30	457	588	780	1295	5493	7062	9366	15549	11.44	10.70	10.41	11.27	4.83	3.76	2.83	1.71
Dec. 07	424	558	763	1326	5091	6699	9165	15912	10.61	10.15	10.18	11.53	4.67	3.55	2.59	1.49
Dec. 14	397	536	761	1369	4764	6438	9141	16434	9.93	9.75	10.16	11.91	4.61	3.41	2.40	1.34
Dec. 21	379	524	765	1418	4551	6297	9183	17016	9.48	9.54	10.20	12.33	4.51	3.26	2.23	1.21
2019-20																
Nov. 30	438	584	776	1273	5256	7011	9312	15285	10.95	10.62	10.35	11.08	4.73	3.54	2.67	1.63
Dec. 07	423	569	764	1310	5082	6834	9168	15720	10.59	10.35	10.19	11.39	4.53	3.37	2.51	1.47
Dec. 14	407	549	753	1359	4887	6597	9045	16317	10.18	10.00	10.05	11.82	4.30	3.18	2.32	1.29
Dec. 21	395	538	756	1420	4749	6459	9075	17046	9.89	9.79	10.08	12.35	4.27	3.14	2.23	1.19
Mean																
Nov. 30	447	586	778	1284	5374	7036	9339	15417	11.19	10.66	10.38	11.17	4.78	3.65	2.75	1.67
Dec. 07	211	284	382	655	2541	3417	4584	7860	5.29	5.17	5.09	5.69	2.26	1.68	1.25	0.73
Dec. 14	415	553	758	1342	4989	6648	9105	16114	10.39	10.07	10.11	11.67	4.48	3.36	2.45	1.39
Dec. 21	396	537	758	1394	4756	6448	9108	16740	9.91	9.77	10.12	12.13	4.44	3.27	2.31	1.26

DAS = Days after sowing; 40 DAS = Knee high stage; 55 DAS = Budding stage; 75 DAS = Flowering stage; 115 DAS = Maturity stage
GDD, Growing degree-days; PTU, Photo-thermal unit; PTI, Photo-thermal index; HUE, Heat use efficiency

in the region, reduce fertilizer usage and maintain soil health, the treatment of 75% RDF + 5.0 t vermicompost ha^{-1} is strongly advocated as an effective alternative.

CONFLICTS OF INTEREST

There exists no conflicts of interest among the authors.

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