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VARIATION IN GROWTH, YIELD AND QUALITY TRAITS OF SPRING SUNFLOWER (*HELIANTHUS ANNUUS* L.) DUE TO SOWING METHOD AND NITROGEN LEVEL UNDER COASTAL AGROECOSYSTEM

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ABSTRACT

The present work was conducted during the spring season of 2022 and 2023 at Regional Research Station (CSZ), B.C.K.V., Akshaynagar, Kakdwip (West Bengal) to study the effect of different sowing methods and N levels on spring sunflower (*cv.* SUN FARM). The field trial was arranged in a strip-plot design with two sowing methods (furrow and pit sowing) in the vertical strips and six N levels (0, 40, 80, 120, 160 and 200 kg/ha) in the horizontal strips. All the measured growth and yield components were found to be significantly higher in furrow-sown crop with 200 kg N/ha. There were significant reductions in yield components and yield when applying less amount of N. Furrow-sown crop on receiving 200 kg N/ha produced the highest seed yield (2.58 t/ha) and stover yield (8.40 t/ha), accounting for 337.29% and 113.20% more than the crop in control plots (without N). The highest seed oil content (38.83%) and protein content (19.60%) were achieved for the crop when sown in furrows and fertilized with 200 kg N/ha. The furrow-sown crop receiving 200 kg N/ha fetched the highest NR (` 60509.10/ha) and BCR (2.02), closely followed by the furrow-sown crop receiving 160 kg N/ ha accounting for NR of ` 54463.85/ ha and BCR of 1.92.

Key words : Coastal region, Economics, Nitrogen, Quality, Sowing method, Sunflower, Yield.

Introduction

Sunflower (*Helianthus annuus* L.) is a short-duration crop (90-110 days) with a high productivity potential of seed and oil (46-52%). The crop has several desirable attributes, namely early maturity, wide adaptation to different soil types and seasons, high per-day productivity, photo-insensitivity, high seed multiplication ratio, drought-evading ability and does well under dried tracts (Bhattacharyya *et al.*, 2015). It is the second most important oilseed crop after mustard in the eastern parts of India and has also been cultivated in significant areas for the last two decades. In recent times, this crop has been included in various crop-intensification programs in non-traditional areas including the Kakdwip region of South 24 Parganas district of West Bengal mainly dominated by the rice-fallow system (Alipatra *et al.*, 2019a). As a result, the area under sunflower in the state has increased by many folds during the past decade reaching 4.36mha in 2021-22, contributing a total of 5.31 MT seed with low productivity of 1218 kg/ha (Indiastat, 2022).

In West Bengal, the cultivation of sunflower is considered to be the best alternative to other oilseed crops owing to its high yield potential under assured irrigation facilities (Alipatra *et al.*, 2019b). The introduction of hybrids in West Bengal has also increased the production potential of sunflower. The crop establishment method is one of the most crucial factors for improving crop yield (Bakht *et al.*, 2011). Our farmers generally follow the age-old practices namely, broadcasting or line sowing in flat bed for sunflower seed sowing, which have numerous disadvantages like uneven distributions of seeds, depth, and scattered seeds lying on the surface being picked up by birds. Hence, the adoption of improved sowing methods may lead to increased seed and oil production of sunflower. Traditionally, sunflower is grown in tribal parts of West Bengal (India) as a subsistence crop mostly under low input conditions and under poor management (imbalanced fertilization with unequal plant stand) (Moitra *et al.*, 2012). Although, recently released sunflower hybrids require high input, especially nutrients (Banerjee *et al.*, 2014). To produce one ton of seed, the sunflower crop removes 47 kg N/haon average (Banerjee *et al.*, 2014). Moreover, nitrogen management was particularly relevant to the coastal environment where nitrogen was inherently deficient and careful N supply is required to ensure high sunflower yields. These soils are prone to water-logging resulting in significant losses of N via denitrification, deep drainage and surface run-off. Though information about N management of spring-planted sunflower crop is lacking in the literature, it was hypothesized that production and quality are highly influenced by the N dose and this requirement is related to the sowing method. The objective of this work was also to study the interaction effect between the sowing method and N applied at different levels on sunflower yield and its components in a coastal environment.

Materials and Methods

The experiment was conducted during the spring seasons (January to April) of 2022 and 2023 at the Regional Research Station (Coastal Saline Zone), Bidhan Chandra Krishi Vishwavidyalaya, Akshaynagar, Kakdwip, South 24-Parganas, West Bengal. The research field is situated in a coastal region at an altitude of 7 m above mean sea level and is intersected by a latitude of 22°40´N and a longitude of 88°18´E. Daily average maximum and minimum temperatures fluctuated between 22.0 to 40.2ºC and 10.5 to 26.5ºC, respectively during the cropping season (January to April). Average relative humidity ranged from 87 to 93%. The total average rainfall during the experimental period was 53.9 mm from January to April. Averaged over 2 years, the amount of evaporation during the cropping season was 205.1 mm with a greater value in March. The soil of the experimental field is clay (composing 25.2% sand, 32.4% silt and 42.4% clay) in texture with an acidic pH of 5.95, an electrical conductivity of 1.52 dS/ m, and 0.62% organic carbon 0.62%. The available N, P_2O_5 and K_2O were 155.0, 97.5, and 325.0 kg/ ha, respectively before the initiation of the experiment. The experiment was laid out in strip-plot design, assigning two sowing methods (FS, furrow sowing; PS, pit sowing) in the vertical strips and six N levels [N_0:0 kg N/ha; N_{40}: 40 kg N/ha; N_{80}: 80 kg N/ha; N_{120}:120 kg N/ha; N_{160}:160 kg N/ha; N_{200}: 200 kg N/ha] in the horizontal strips. The experiment consisted of 4 replications with 12 treatment combinations. The total number of plots was 48 with an individual plot dimension of 12m^2 (4m × 3m). The hybrid sunflower variety 'SUN FARM' was grown as the test crop which is produced and marketed by AgriBee Seeds Private Limited, Rajkot, Gujarat (India) and suitably grown particularly in the *rabi* as well as spring season. Seeds were sown on January 21 in both the years. All treatments received the same amount of phosphorus (40 kg/ha) and potassium (40 kg/ha) through single super phosphate (16% P_2O_5) and muriate of potash (60% K_2O), respectively. The entire dose of SSP and MOP were added to the soil before sowing in each plot. Urea was applied in two equal splits at sowing and 33 days after sowing (DAS), as per treatment details. Altogether nine irrigations were provided to the crop from January 21 to March 31 (during 0 to 69 DAS) to fulfil the demand of the crop. One hand weeding was done on February 11 (at 21DAS) to promote early crop growth. The crop was harvested on May 1 (at 100 DAS) in both years when all the plants reached the physiological maturity stage.

Plant growth and yield-determining traits were recorded from 10 randomly selected plants in each plot. Above-ground biomass was evaluated by harvesting 3 representative plants per replicate of each treatment. The N uptake was calculated as the product of crop dry weight and the N concentrations in the plant tissues. Seed and stover yield were estimated plot-wise and then converted into t/ha.

Oil content (%) in sunflower seed was determined by taking seed samples (100 g) from the harvest of each plot. The seeds were ground and taken together with solvent (Hexane) washings to a Soxhlet's apparatus for extraction of oil at 60°C for about 12 hours (AOAC, 2005). The hexane dissolved in extracted sunflower oil was then evaporated using a rotary vacuum and boiling water bath, and the oil percentage was determined after a constant weight was obtained. Oil yield was calculated using the following formula (Welch, 1969).

$$Y_O = \frac{O_C \times Y_S}{100}$$

Where, Y_O is oil yield in kg/ ha; O_C is oil content in %; Y_S is seed yield in kg/ ha.

Protein content in sunflower grain (%) was estimated by multiplying total nitrogen content by 6.25 (Sadasivam and Manickam, 1996). Protein yield was calculated using the following formula given by Takeda and Frey (1985).

$$\text{Protein yield}\left(\text{kg/ha}\right)=\frac{\text{Protein content}\left(\%\right)\times\text{Grain yield}\left(\text{kg/ha}\right)}{100}$$

The economic assessment in terms of cost of cultivation, gross return, net return and benefit: cost ratio of hybrid sunflower cultivation was worked out based on prevailing market price in respective years and then averaged over 2 years.

All the data recorded in the present study were subjected to analysis of variance (ANOVA) appropriate to strip-plot design (Gomez and Gomez, 1984). The homogeneity of variance over both years was tested by performing Bartlett's chi-square test. Finally, pooled values are used to draw logical inferences. Then, a comparison of treatment means was carried out using the critical difference (CD) at a 5% probability level. Excel software (version 2007, Microsoft Inc., WA, USA) was used to draw figures.

Results and Discussion

Growth attributes

The plant height of the sunflower crop was not significantly influenced by sowing methods, but other growth attributes varied significantly due to this factor (Table 1). The furrow-sown crop had significantly higher basal stem girth at 100 DAS (8.92 cm), LAI at 100 DAS (3.75) and CGR during 75-100 DAS (16.8 g/m^2/day), registering 20.21%, 25.42% and 54.84% more than that of the pit-sown crop. But the reverse was true for a number of leaves/plant and pit sown crop possessed a significantly higher number of leaves/plant (29.5) than the furrow-sown crop (27.61). Furrow sowing (at shallow depth) not only exhibited quick emergence but also accelerated growth of the crop resulting in higher plant height, LAI and CGR. Furthermore, furrow-sown crop showed a significant increase in plant biomass, which might have been due to better use of soil and moisture. On the contrary, the emergence was a little delayed for pit-sown crop due to the deep placement of seeds, and thereby exhibited comparatively less crop growth. Nitrogen application caused significant improvement in the growth characteristics of the test crop (Table 1). All measured growth attributes increased with successive increases in N level up to the highest level of application (200 kg/ha). On receiving 200 kg N/ha, sunflower plants attained greater height (168.67 cm) and possessed a higher number of leaves (31.33) at 100 DAS, registering 22.81% and 25.32% more than that of the control treatment (without N). However, both plant height and the number of leaves/plants were not reduced significantly due to low N application (160, 120 and 80 kg/ha). The highest dose of N (200 kg/ha) also had a greater impact on crop growth in terms of basal stem girth (9.25cm) at 100 DAS, LAI at 100 DAS (4.49) and CGR during 75-100 DAS (16.64 g/m^2/day), compared to other N rates. As compared to the control treatment (without N), the above increment was to the tune of 48.0%, 105.0%, and 41.9%, respectively. However, the variation in basal stem girth of plants at 100 DAS was non-significant due to low N application rates (160 and 200 kg/ha). These results suggest that, a higher N dose significantly increases leaf chlorophyll content, cell division, and elongation which consequently increases the leaf area, and overall plant biomass. Cechin and Fumis (2004) also found that the sunflower height and shoot dry matter in plots of ample N were significantly higher compared to the plants in plots without N. Yadav *et al*. (2009) also registered maximum plant height and other growth attributes with higher N supply (125 kg/ha). The interaction effect (sowing method × N levels) failed to record any significant variation in height and number of leaves per plant (Table 2). However, it showed significant variation in basal stem girth, leaf area, and CGR. Plants raised with furrow sowing and 200kg N/ha caused significant improvement in basal stem girth (10cm) at 100 DAS, LAI (4.60) at 100 DAS, and CGR during 75-100 DAS (18.51 g/m^2/day) over other treatment combinations.

Above-ground biomass and N uptake

Large significant differences were found in the above-ground biomass (AGB) of plants due to various sowing methods and N levels (Fig. 1). The interaction effect (sowing methods × N levels) on above-ground biomass was significant at all dates of observation (Fig. 1). However, the application of 200 kg N/ha resulted in higher AGB of pit-sown crop at 75 DAS and furrow-sown crop at 100 DAS. The test crop when sown in furrows and fertilized with 200 kg N/ha registered the highest AGB at 100 DAS (208.77 g), accounting for 100.34% more AGB produced by plants sown in pits (without N). This may be due to N effects on cell elongation. Nitrogen, being the principal component of proteins, enzymes, hormones, vitamins and chlorophyll, accelerates the meristematic activity of plants, which leads to progressive increases in internode length, protein synthesis and photosynthetic area, ultimately resulting in higher plant height and dry matter production (Biswas and Poddar, 2015). Increased total biomass with increasing dose of N might be the reason for greater absorption of nitrogen from the soil, resulting in higher total uptake of N (Yadav *et al*., 2009). In the present study, the AGB of

Table 1 : Effect of sowing methods and N levels on growth attributes and yield determining traits of spring sunflower (pooled data of 2 years).

Treatments	Plant height (cm) at 100 DAS	No. of leaves/ plant at 100 DAS	Basal stem girth (cm) at 100 DAS	LAI at 100 DAS	CGR ($g/m^2/day$) during 75-100 DAS	Capitulum diameter (cm)	Capitulum weight with seeds (g)	Capitulum weight without seeds (g)	No. of seeds/ capitulum	Seed weight/ capitulum (g)	100 seed weight(g)
Sowing methods											
FS	157.82	27.61	8.92	3.75	16.80	22.00	64.07	16.52	703.39	47.55	4.75
PS	157.06	29.50	7.42	2.99	10.85	19.58	58.43	16.02	642.26	42.41	4.41
SEm±	1.42	0.28	0.03	0.06	0.05	0.21	0.08	0.08	2.92	0.02	0.03
CD (P=0.05)	NS	1.24	0.14	0.28	0.21	0.96	0.35	0.37	13.15	0.10	0.13
N levels											
N_0(Control)	137.34	25.00	6.25	2.19	11.73	16.75	38.42	8.35	390.89	30.07	2.91
N_{40}	146.17	27.33	7.50	2.93	11.55	18.00	46.31	10.10	459.35	36.22	3.23
N_{80}	162.33	28.83	8.00	3.38	12.37	20.25	64.64	17.28	671.04	47.36	4.75
N_{120}	164.29	29.17	8.75	3.50	15.67	22.00	68.82	20.03	809.27	48.79	5.31
N_{160}	165.84	29.67	9.25	3.74	15.00	23.25	73.16	21.01	838.93	51.85	5.60
N_{200}	168.67	31.33	9.25	4.49	16.64	24.50	76.45	20.87	867.49	55.59	5.70
SEm±	3.16	1.01	0.05	0.09	0.05	0.31	0.11	0.12	4.07	0.10	0.07
CD (P=0.05)	9.52	3.05	0.14	0.28	0.15	0.94	0.32	0.37	12.27	0.29	0.22

FS, Furrow sowing; PS, Pit Sowing; Subscript digits signify respective dose of N in kg/ha; LAI, Leaf area index; CGR, Crop growth rate; NS, Non-significant.

plants grown without N supply was reduced due to inhibition of growth rate as well as impaired N transport to the plants.

Total N uptake by hybrid sunflower gradually increased as the crop age progressed towards maturity (Fig. 2). The data on total N uptake varied widely under different sowing methods and N levels at all dates of observation. Pit-sown crop when fertilized with 200 kg N/ha recorded significantly higher total N uptake (0.27 kg/ha) than furrow-sown crops at 25 DAS; being statistically at par with N uptake (0.26 kg/ha) by furrow-sown crop at the same rate of N supply. However, a dissimilar trend was obtained in other dates of observations. The furrow-sown crop when fertilized with 200 kg N/ha resulted in significantly higher total N uptake by the test crop at 50 DAS (8.32 kg/ha), 75 DAS (138.00 kg/ha) and 100 DAS (231.09 kg/ha). The possible reason could be that the furrow sowing provided aerated soil and favourable environment to the plants which helped in more nutrient absorption, especially N (Ahmad *et al*., 2000). In addition to that, furrows might have provided a better soil environment for easy root penetration which triggered nutrient uptake from soil. Krishnamurthy *et al*. (2011) also observed that increasing levels of N application had a positive influence on the total N uptake by sunflower.

Yield determining traits

The superiority of furrow-sown crop was observed over pit-sown crop with respect to all yield-determining traits (Table 1). Significantly higher capitulum diameter (22cm), capitulum weight with (64.07g) and without seeds (16.52g), number of seeds/ capitulum (703.39), seed weight/ capitulum (47.55g) and 100-seed weight (4.75g) was obtained in crops raised under furrow sowing, registering 12.36%, 9.65%, 3.12%, 9.52%, 12.12% and 7.71% more than the crops raised under pit sowing. Furrow sowing afforded them more efficient utilization of available resources to grow well and to increase

Table 2 : Interaction effect (sowing methods × N levels) on growth attributes and yield determining traits of spring sunflower (pooled data of 2 years).

Treatment combinations (sowing methods × N levels)	Plant height (cm) at 100 DAS	No. of leaves/ plant at 100 DAS	Basal stem girth (cm) at 100 DAS	LAI at 100 DAS	CGR (g/m^2/day) during 75-100 DAS	Capitulum diameter (cm)	Capitulum weight with seeds (g)	Capitulum weight without seeds (g)	No. of seeds/ capitulum	Seed weight/ capitulum (g)	100 seed weight(g)
FS× N_0	134.67	24.00	7.00	2.90	16.81	19.00	41.27	8.06	437.59	33.21	3.23
FS× N_{40}	149.33	26.67	8.50	3.40	16.41	21.00	54.28	11.01	561.77	43.27	3.49
FS× N_{80}	163.33	27.67	8.50	3.71	15.24	21.50	65.88	17.48	673.32	48.40	4.97
FS× N_{120}	164.58	28.00	9.50	3.91	16.83	22.00	70.07	19.47	819.71	50.60	5.45
FS× N_{160}	166.00	28.33	10.00	3.97	17.01	23.50	75.94	23.04	852.23	52.29	5.62
FS× N_{200}	169.00	31.00	10.00	4.60	18.51	25.00	77.57	20.07	875.73	57.50	5.71
PS× N_0	140.00	26.00	5.50	1.47	6.66	14.50	35.57	8.64	344.19	26.93	2.58
PS× N_{40}	143.00	28.00	6.50	2.45	6.69	15.00	38.34	9.18	356.93	29.16	2.96
PS× N_{80}	161.33	30.00	7.50	3.04	9.50	19.00	63.39	17.07	668.75	46.32	4.52
PS× N_{120}	164.00	30.33	8.00	3.09	14.51	22.00	67.57	20.59	798.83	46.98	5.17
PS× N_{160}	165.67	31.00	8.50	3.51	12.99	23.00	70.38	18.98	825.62	51.40	5.57
PS× N_{200}	168.33	31.67	8.50	4.37	14.76	24.00	75.33	21.66	859.24	53.67	5.68
Sowing methods ×N levels											
SEm±	3.46	1.31	0.08	0.11	0.12	0.52	0.13	0.14	4.84	0.09	0.08
CD(P=0.05)	NS	NS	0.26	0.33	0.36	1.57	0.40	0.43	14.60	0.26	0.25
N levels × Sowing methods											
SEm±	3.89	1.36	0.08	0.12	0.10	0.49	0.14	0.15	5.22	0.11	0.09
CD(P=0.05)	NS	NS	0.23	0.36	0.31	1.48	0.41	0.47	15.76	0.33	0.28

FS, Furrow sowing; PS, Pit Sowing; Subscript digits signify respective dose of N in kg/ha; LAI, Leaf area index; CGR, Crop growth rate; NS, Non-significant.

yield-determining traits (Bindu *et al.*, 2017). The response to nitrogen was expected and sunflower yield determining traits, regardless of sowing methods, increased significantly with an increase in N supply up to 200 kg/ha (Table 1). The highest N application rate (200 kg/ha) resulted in maximum capitulum diameter (24.50cm), capitulum weight with seed (76.45g), number of seeds/ capitulum (867.49) and seed weight capitulum (55.59g). The extent of increment was to the tune of 46.27%, 98.98%, 121.93% and 84.87% respectively over control treatment (without N). In addition to this, 100-seed weight (5.70 g) was obtained from the crop receiving 200kg N/ha and it did not decline significantly due to successive reduction of N level from 200 to 160 kg/ha(5.60g). The increment of capitulum diameter and weight could be due to sufficient availability of N, which is responsible for cell division and cell elongation. At higher N supply, plants faced less competition for N demand, thus facilitating more photosynthates accumulation into the sink (Banerjee *et al.*, 2014). This result might further be attributed to the decreased number of infertile kernels with sufficient N supply (Alipatra *et al.*, 2019a). The improvement of 1000-grain weight with increasing dose of N was observed as a result of increased kernel size, which is nothing but the resultant effect of enough food storage and accumulation of photosynthates to grains (Alipatra *et al.*, 2019b). Ultimately, better utilization of N resulted in bold and robust (healthy) seed size with successive increases in N supply. The interaction effect (sowing methods × N levels) on various yield-determining traits of the test crop was found to be significant (Table 2). Furrow-sown crop on receiving 200kg N/ha gave significantly higher capitulum diameter (25cm), capitulum weight with seeds (77.57g), number of seeds/ capitulum (875.73), seed weight/ capitulum (57.50g) and 100-seed weight (5.71g) than other treatment combinations. But, capitulum weight without seeds was significantly higher in the case of furrow sown crop receiving 160 kg N/ha.

Seed and stover yield

Crops under furrow sowing out-yielded crops under pit sowing significantly with respect to seed yield and stover yield (Table 3). The seed yield (1.74 t/ha) and stover yield (6.14 t/ha) of the furrow-sown crop were significantly 14.47% and 7.91% higher than that of the pit-sown crop. Even HI was significantly higher in the case of the furrow-sown crop (20.88%), accounting for 11.72% more than that of the pit-sown crop. Sunflower yields varied widely and significantly at different levels of N. The highest seed yield (2.55 t/ha) and stover yield (8.19 t/ha) were recorded with the supply of 200 kg N/ha accounting for 479.55% and 132.01% more than the

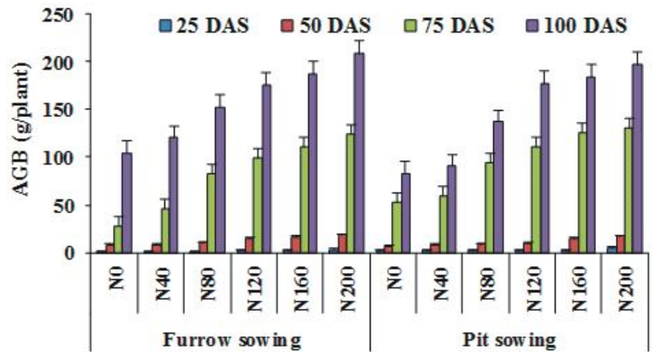

Fig. 1 : Above-ground biomass (AGB) of spring sunflower as influenced by the interaction of sowing methods and N levels.

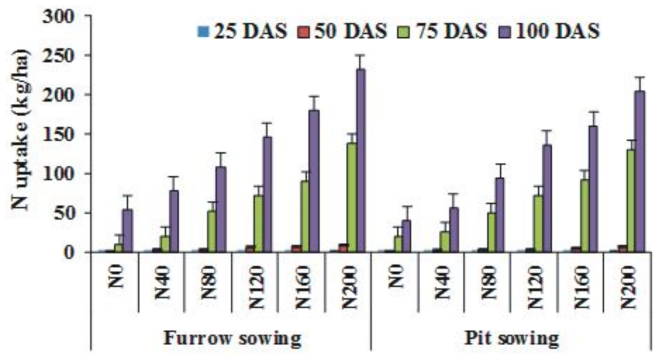

Fig. 2 : Nitrogen (N) uptake by spring sunflower as influenced by the interaction of sowing methods and N levels.

yields obtained in the control plot (without N). In this present study, positive association was documented between seed yield and AGB (R^2 = 0.984) and seed yield and total N uptake (R^2 = 0.902), as depicted in Fig. 3 (a and b). Hence, it can be postulated that more AGB and N uptake will be more likely to change or improve the seed yield of hybrid sunflower in the spring season, irrespective of sowing methods and N levels. According to Krishnamurthy *et al.* (2011) higher head diameter, number of seeds/ capitulum and heavier seeds facilitate yield increase in sunflower. Another possible reason for such yield increase could be the production of more number of kernels/ capitulum and heavier kernels with the highest N supply. In the present study, the application of 160 kg N/ha recorded maximum HI (24.41%). However, HI was not changed significantly due to low (120 kg/ha) and high rate (200 kg/ha) of N supply. In the present study, plants in control plots under (without N) both sowing methods showed marked reduction in yield attributes namely seeds per capitulum, seed weight per capitulum, 100-seed weight and seed yield. Low pollen formation under low N supply (0 to 80 kg/ha) might be the key reason for poor grain development in the capitulum. These results substantiate the findings of Rondanini *et al.* (2007) and Cantagallo *et al.* (2009), who also reported that the shortage of N affects the growth and

Table 3 : Effect of sowing methods and N levels on yield, harvest index and quality of spring sunflower (pooled data of 2 years).

Treatments	Seed yield (t/ha)	Stover yield (t/ha)	Harvest index (%)	Oil content (%)	Oil yield (kg/ha)	Protein content (%)	Protein yield (kg/ha)
Sowing methods							
FS	1.74	6.14	20.88	34.25	621.30	14.01	269.31
PS	1.52	5.69	18.69	33.78	539.34	12.81	219.63
SEm±	0.02	0.01	0.19	0.04	5.98	0.07	2.40
CD (P=0.05)	0.07	0.03	0.84	0.17	26.93	0.30	10.81
N Levels							
N_0(Control)	0.44	3.53	10.76	29.57	130.90	9.19	41.64
N_{40}	0.64	3.85	13.69	30.97	198.83	10.85	69.73
N_{80}	1.57	5.40	22.53	33.92	532.43	11.64	182.93
N_{120}	2.19	7.08	23.61	34.88	764.24	13.96	306.02
N_{160}	2.41	7.45	24.41	36.02	868.95	16.13	389.36
N_{200}	2.55	8.19	23.70	38.72	986.56	18.73	477.13
SEm±	0.04	0.01	0.31	0.03	15.54	0.06	7.40
CD (P=0.05)	0.11	0.03	0.93	0.10	46.84	0.17	22.31

FS, Furrow sowing; PS, Pit Sowing; Subscript digits signify respective dose of N in kg/ha.

development of both source and sink, and the number of seeds/ capitulum. Furthermore, N-stress or deficiency causes disturbance in the balance of the nutritional environment in plants, which also has adverse effects on plant growth and ultimately reduces the yield of sunflower (Alipatra *et al*., 2019a). The interactive effect of studied factors (sowing methods × N levels) on seed and stover yield of test crop were found significant (Table 4). The furrow-sown crop with 200 kg/ha produced the highest seed yield (2.58t/ha) as well as stover yield (8.40 t/ha). However, the furrow-sown crop with 120 kg N/ha produced the highest HI (24.74%) than all other treatment combinations. Irrespective of sowing methods, N application beyond 120 kg/ha failed to increase HI of test crop, rather HI was declined with N supply beyond 160 kg/ha.

Quality of seeds

Both factors (sowing methods and N levels) caused significant variation in the quality traits of the test crop (Table 3). The test crop recorded significantly higher seed oil content (34.25%), oil yield (621.30 kg/ha), protein content (14.01%) and protein yield (269.31 kg/ha) when sown in furrows, registering 1.39%, 15.2%, 9.37% and 22.62% more than that obtained in the pit-sown crop. Moreover, application of 200 kg N/ha recorded a greater amount of seed oil content (38.72%), oil yield (986.56 kg/ha), protein content (18.73%) and protein yield (477.13 kg/ha), accounting for 30.94%, 653.67%, 103.81% and

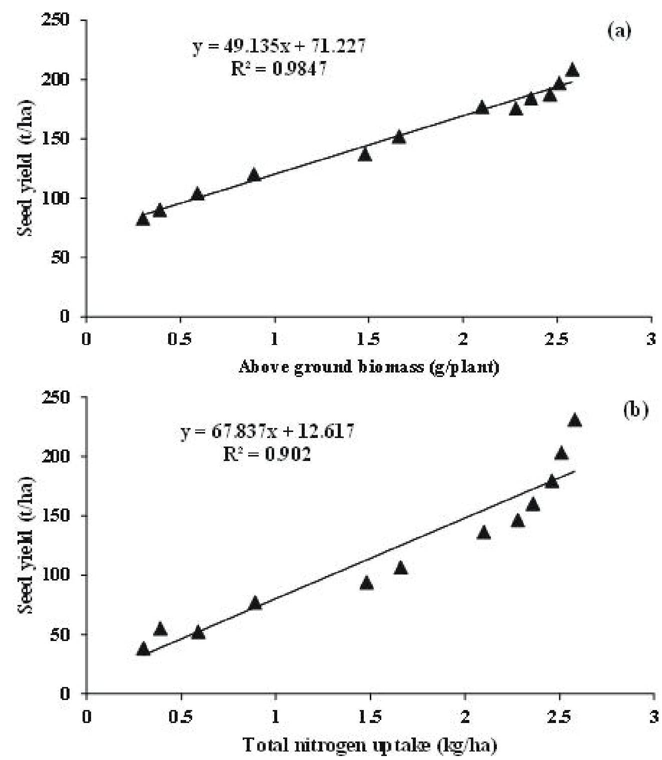

Fig. 3 : (a and b)- Relationship between seed yield and AGB (a) and seed yield and total N uptake (b) in spring sunflower plant.

1045.85% more than the plants in control plots (without N). Shekhawat and Shivay (2008) also opined that N application has positive relations with grain protein content. Moreover, the higher oil content and oil yield obtained

Table 4 : Interaction effect (sowing methods × N levels) on yield, harvest index and quality of spring sunflower (pooled data of 2 years).

Treatment combinations (sowing methods × N levels)	Seed yield (t/ha)	Stover yield (t/ha)	Harvest Index (%)	Oil content (%)	Oil yield (kg/ha)	Protein content (%)	Protein yield (kg/ha)
FS× N_0	0.59	3.94	12.93	29.78	174.73	9.89	57.97
FS× N_{40}	0.89	4.30	17.15	31.11	277.55	10.94	97.76
FS× N_{80}	1.66	5.76	22.35	33.57	557.35	11.73	194.54
FS× N_{120}	2.28	6.94	24.74	35.27	805.43	14.61	333.49
FS× N_{160}	2.46	7.52	24.63	36.92	910.20	17.33	426.49
FS× N_{200}	2.58	8.40	23.47	38.83	1002.55	19.60	505.60
PS× N_0	0.30	3.13	8.58	29.36	87.07	8.49	25.31
PS× N_{40}	0.39	3.40	10.23	30.83	120.10	10.76	41.71
PS× N_{80}	1.48	5.03	22.71	34.26	507.50	11.55	171.31
PS× N_{120}	2.10	7.22	22.49	34.48	723.06	13.30	278.55
PS× N_{160}	2.36	7.38	24.18	35.12	827.71	14.94	352.22
PS× N_{200}	2.51	7.98	23.94	38.60	970.58	17.85	448.67
Sowing methods × N levels							
SEm±	0.03	0.02	0.40	0.08	13.17	0.15	5.75
CD(P=0.05)	0.10	0.06	1.19	0.25	39.70	0.46	17.34
N levels × Sowing methods							
SEm±	0.04	0.02	0.41	0.07	17.24	0.13	7.98
CD(P=0.05)	0.12	0.05	1.24	0.22	51.97	0.39	24.05

FS, Furrow sowing; PS, Pit Sowing; Subscript digits signify respective dose of N in kg/ha.

Table 5 : Economics assessment of spring sunflower cultivation per hectare as influenced by sowing methods and N levels (pooled data of 2 years).

Treatment combinations (sowing methods × N levels)	Cost of cultivation (` /ha)	Gross return (` /ha)	Net return (` /ha)	Benefit-cost ratio
FS× N_0	55277.00	31480	-23797.00	0.57
FS × N_{40}	57103.80	44200	-12903.80	0.77
FS × N_{80}	57618.55	77920	20301.45	1.35
FS × N_{120}	58133.35	105080	46946.65	1.81
FS × N_{160}	58976.15	113440	54463.85	1.92
FS × N_{200}	59490.90	120000	60509.10	2.02
PS× N_0	58557.00	18260	-40297.00	0.31
PS × N_{40}	60383.80	22400	-37983.80	0.37
PS × N_{80}	60898.55	69260	8361.45	1.14
PS× N_{120}	61413.35	98440	37026.65	1.60
PS× N_{160}	62256.15	109160	46903.85	1.75
PS× N_{200}	62770.90	116360	53589.10	1.85

FS, Furrow sowing; PS, Pit Sowing; Subscript digits signify respective dose of N in kg/ha.

with higher N supply might be due to enzymatic action in the formation of glucosides, glucosinolates and additionally, sulphydril-linkage in biochemical reaction within the plant which ultimately helps in the biosynthesis of oil (Kundu *et al*., 2023). The interactive effect (sowing methods × N levels) on seed oil content, oil yield, protein content, and protein yield of test crop was found to be significant (Table 4). The furrow-sown crop with 200 kg N/ha produced seeds having higher oil (38.83%) and protein (19.60%) content. The trend was exactly the same for oil yield and oil content.

Production economics

Irrespective of N levels, the total cost of cultivation differed on account of two sowing methods and it was more in case of pit-sown crop than furrow-sown crop due to higher labour engagement in the former case (Table 5). The economic benefit of hybrid sunflower cultivation was found to vary due to the interaction effect of studied factors (sowing methods × N levels). The furrow-sown crop receiving 200 kg N/ha fetched the highest gross return (` 120000/ha), net return (` 60509.10/ha) and benefit-cost ratio (2.02). The next best return was achieved with furrow sown crop receiving 160 kg N/ha, accounting net return of ` 54463.85/ha and a benefit-cost ratio of 1.92. This obvious response was due to the realization of higher seed and stover yield in the former case. Economic loss (negative values of net return) was noticed for the crops receiving 0 and 40 kg N/ha, regardless of sowing methods and that might be due to poor crop growth and productivity. These results are in partial agreement with the finding of Pattanayak *et al*. (2017), who reported that net returns and benefit-cost ratio were relatively low with farmer fertilizer practice (having low N supply) and increased to the highest level at a balanced fertilizer rate.

Conclusion

The above results highlight the importance of determining the interaction effect of the sowing method and N levels on the yield of sunflower to formulate proper management practices for sustainable production. The management practice, consisting of furrow sowing (at shallow depth) and N supply @ 200 kg/ha, is a better proposition for achieving higher productivity and economic gain in spring sunflower cultivation under the coastal agro-ecosystem of West Bengal.

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