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Research Article

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NITROGEN USE EFFICIENCY IN SUNFLOWER (*HELIANTHUS ANNUUS* L.) INFLUENCED BY VARIOUS FERTIGATION AND BED PLANTING TECHNIQUES

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ABSTRACT

Low nitrogen fertilizer use efficiency and high losses of nitrogen are the critical challenges being faced by sunflower grower. To address these concerns, an experiment was carried out during spring 2021 at the Agronomic research area of the Agriculture University, Faisalabad. The randomized complete block design experiment was used with three replications under split plot arrangement. The 5m x 3m net plot size was kept with sowing procedures retained in the main plot and nitrogen application techniques kept in the sub plot. The experiment was planted on 20-02-2021. The matured crop was reaped on 18 June, 2021 manually. The single row hand drill was used to sow sunflower crop. The 75 cm line to line and 25 cm plant to plant distance was maintained. The results indicated that plant population ranged from 73 to 74 with maximum plant height of 174.33 cm, stem diameter (3.70 cm), head diameter (23.13 cm), number of achenes per head (1237.6), 1000-achene weight (68.17 g), highest biological yield (10.92 t ha^{-1}), achene yield (3.22 t ha^{-1}), harvest index (29.48 %) and protein contents (29.03 %) was observed in treatment where nitrogen was applied by fertigation method and sunflower was sown on beds. But maximum oil contents (41.78 %) were observed where nitrogen was side dressed and flat sowing technique was adopted for crop sowing. It is found that use of fertigation method of nitrogen application and bed planting techniques proved to be the best combination for improving growth, yield & yield relating attributes and improve fertilizer use efficiency with lower nitrogen losses for sunflower (Hybrid-33) under agro-climatic conditions of Faisalabad.

Key words: Sunflower hybrid, N efficiency, fertigation, ridge sowing, yield

INTRODUCTION

Sustainable agriculture is the need of time and stable growth of crops is crucial for food security in world in general and especially in Pakistan. It makes a substantial contribution to employment and foreign exchange revenues. It also offers industrial raw materials, which aids expansion. This industry has several connections to the rest of the economy. There is 22.7 percent share of Agriculture sector in the GDP of Pakistan. It provides employment to about 37.4 percent of the rural landscape and environmental shield in the protection and enhancement of climate-resilient production and ecology (Govt. of Pakistan, 2022).

Agriculture sector grew by 4.40 percent in 2021-22 with 3.50 percent above the growth target. This development is largely contributed by higher crops yield, attractive supportive produce prices and good government policies, as well as increasing availability of certified seeds, pesticides, and agricultural financing. A total worth value of Rs 662.657 billion used expended for import of about 2.754 million tons of edible oil/oil from oilseed for crushing in Financial year 2022. During this time period, the local edible oil output is expected to be 0.460 million tons. The total available edible oil over this time period is expected to be 3.214 million tons (Govt. of Pakistan, 2022).

Sunflower (*Helianthus annuus* L.), previously utilized as a decorative plant, has recently emerged as a major source of food oil. As a fodder crop, sunflower is very valuable and is either fed in green form or preserved as hay or silage. Sunflower stood at second rank to soybean for production and extraction of edible oil in the world. The sunflower oil signifies approximately 15 percent of the world oil production (Ahmed *et al.*,2023).

Pakistan is the 3rd leading importer of edible oil which spends huge foreign exchange earnings on the import of edible oil. This import bill is second largest to that spends on the import of mineral oil. At present Pakistan can fulfill 31% of its edible oil requirement from domestic production while remaining 69% is imported from other countries. In Pakistan, total area under sunflower cultivation is 253000 acres while the total annual seed production is 141000 tones providing an oil production of 54000 tones. In Punjab, Pakistan, total area under sunflower cultivation is 49450 acres

with the total annual seed production is 48200 tones providing an average yield of 2.44 tones per hactare (Govt. of Pakistan, 2022). The increased import of vegetable oil is putting a strain on the national economy. All of this needs a greater focus on increasing domestic oil-seed output.

There are two types of oilseed crops being grown in Pakistan i.e. Traditional and non-traditional. Traditional crops include sesame, rapeseed, castor bean, groundnut and linseed), while safflower sunflower and soybean are non-traditional oilseed crops. Sunflower as a non-traditional crops has the potential to close the breach between national production and edible oil import. Oil contents of 25-48% and protein contents of 20-27% are present in seed of sunflower (Ahmed *et al.*,2023). Sunflower oil is delicious and high in A, D, E, and K vitamins. It is also used in the making of margarine. Sunflower cake is served to cattle as a palatable feed.

Appropriate sowing techniques are necessary for obtaining high yield of sunflower. Ridge sown sunflower gives higher seed and oil yield due to large sized disc, more number of seeds than that sown in flat pattern. Plantation of sunflower on beds result in high water use efficiency and soil moisture conservation practices (Bakheit *et al.*,2022). Bed planting has the potential to significantly improve irrigated sunflower-based agricultural systems by making them less resource demanding and more sustainable.

Bed planting, even without conservation tillage, provides new and improved weed control, water management, and fertilizer management options, as well as reduced crop lodging and some tillage reduction. Farmers say that with the right variety, yields in bed plantation can be increased by at least 10%, production costs may be lowered by 20-30%, and irrigation water requirements can be decreased by up to 35% when compared to standard flat planting (Ahmed *et al.*,2023)

Because to improper application procedures, fertilizer yield is far lower than real potential. It has been noted that applied fertilizer may be wasted owing to run-off and leaching, which might have been utilized efficiently with suitable application methods. It has also been found that applying mixed fertilizer in a band below the seed appears to be the most efficient in terms of phosphorous uptake and plant development. It has also been stated that the side banding approach outperforms broadcast. To achieve maximum fertilizer efficiency, optimal fertilizer volumes must be combined with suitable application timing and manner (Chandio *et al.*,2022)

Fertigation seems the best fertilizer management approach for intensive sustainable agriculture, as it increases efficiency of fertilizers, increases yield, protects environment, and sustained irrigated agriculture. It is a highly sophisticated strategy in which nutrients are delivered via irrigation water to reach crop roots quickly and with little soil involvement. Fertilizer placement is an essential component of effective crop management (Dan *et al.*,2022).

Among the main elements, N plays an important role in plant growth by increasing protein synthesis, cell size, and photosynthetic activity. N absorption and yield were higher when N was used as a band placement approach rather than a broadcast strategy. Similarly, the side drilling approach has been proven to be superior for producing high-quality seed (Dan *et al.*,2022).

Use of proper N application technique is also of great importance to increase fertilizer use efficiency. Urea placed 4 cm below the seed row and drilled 5 cm to one side of the seed row as a side dressing produced more leaf area per plant, head size, seed number per head, 1000-grain weight, and seed yield than urea broadcast treatment (Hasanvand *et al.*,2023).

Keeping in view the above facts, present study was conducted to investigate the effect of different nitrogen application methods on growth, yield and quality of sunflower hybrid sown by employing different techniques under agro-climatic conditions of Faisalabad.

MATERIALS AND METHODS

This research experiment was conducted to study the response in a spring-planted sunflower to different sowing procedures and nitrogen application strategies. The experiment was planted in the spring season of the year 2021 at the Research Farm of Agronomy at the Agriculture University Faisalabad, Punjab, Pakistan. The following treatments were used in the research experiment: -

Treatments

Sowing Techniques (main plot):

S_1= Flat sowing technique

S_2= Ridge sowing technique

S_3= Bed sowing technique

Nitrogen application methods (sub plot):

F_1= Fertigation

F_2= Band placement

F_3= Side dressing

Layout: The randomized complete block design (RCBD) under split plot arrangements with three replications was used in the layout of the experiment. The net plot dimension was 5.0 m x 3.0 m. Sowing procedures were retained in the main plot, whereas nitrogen application methods were kept in the sub plot.

Crop Husbandry: The seedbed was prepared by cultivating the field 2-3 times with a tractor-mounted cultivator, followed by planking. The crop was planted on February 20, 2021, and collected manually on June 18, 2021. Sowing was done in 75 cm apart rows with the aid of a single row hand drill. Plant to plant spacing of 25 cm was maintained by thinning at the four leaf stage. Nitrogen was administered at a rate of 150 kg ha^{-1}, and phosphorus was applied at a rate of 100 kg ha^{-1} in the form of urea and DAP.

All phosphorus and half of the nitrogen were drilled using the seed cum fertilizer drill at the time of sowing, and the remaining half of the nitrogen was given by band placement, side dressing, and fertigation. The first irrigation was applied after 20 days after seeding, and additional irrigations were applied based on crop needs. All other agronomic procedures were kept normal and consistent across all treatments. Plant protection measures were used to preserve the crop free of weeds, insect pests, and illnesses by hoeing twice during the growing season.

Observations recorded: During the investigation, the following observations were made:

Agronomic and yield related traits: When the crop is fully matured, or 110 days old, the following traits related to agronomic and yield contributing factors, which include germination, plant height, plant population per plot, stem diameter at maturity, one thousand achene weight, diameter of head, achenes number per head, biological and achene yield, along with harvest index, were evaluated taken.

Quality Parameters: During the research work, following quality parameters were documented.

1. Oil contents (%)
2. Protein contents (%)

Statistical Analysis:Standard techniques were used to gather data on all the parameters, and ANNOVA (analysis of variance) of Fisher's was used to evaluate and compare means of the data. The LSD test for sowing techniques, fertilizer application methodology and their interaction with a 5% probability was employed to evaluate the variations in treatment means (Steel *et al.,* 1997).

Procedure To Record Observations:

Agronomic and yield related traits: To determine the total number of plants in each plot at maturity, the number of plants in each plot were counted at harvest. Ten plants were randomly chosen from each subplot to measure plant height (in centimeters). Using a measuring tape, their heights were recorded in "cm," and the results were averaged. Using Vernier callipers, the stem diameter of 10 plants was measured from the base, middle, and top, and the average was calculated. Using a measuring tape, the diameter of 10 randomly chosen heads was measured in "cm," and the head diameter (cm) was calculated by averaging the measurements.

Ten randomly chosen heads from each treatment had their achene counted, and the average number of achene per head was calculated. To determine the average weight of 1000-achenes in grams, ten samples, each consisting of 1000-achenes, were randomly selected from the seed lot of each plot. Sun-dried sunflower crop was harvested for biological yield (t ha^{-1}). Following the individual weighing of the biomass in each plot, the biological yield per hectare in tons was computed. After harvesting, the achene yield (t ha^{-1}) was calculated at maturity. Each head was separated, sun dried, threshed, and the achene yield per plot was then recorded for this purpose. The yield of achene was then converted to t ha^{-1}. The harvest index shows the proportion of biological yield to achene output. It was computed using the following relation for every plot.

$$Harvest\ index\ (\%)\ = (Achene\ yield/biological\ yield)100$$

Quality parameters: The Soxhlet Fat Extraction technique was used to assess the oil content (%) in seeds (AOAC, 1990). For almost eight hours, seeds were dried in an oven set at 105°C. The moisture content of the seeds was measured by weighing them both before and after drying. A coffee grinder was used to grind two grams of achenes each thimble for analysis. After weighing each tumbler independently and adding pulverized seeds, the total weight was noted. The thimbles were then put into extractors. Six round-bottom flasks that were dry and clean were weighed, and the weight was noted. The flasks were filled with petroleum ether, linked to extractors, set on heating mantles, then connected to condensers after that.

At least six hours of extraction time were spent heating the flasks. In order for all of the solvent to be gathered in the Soxhlet extractors, the extraction was then halted, the thimbles were taken out, and the flask was heated. After letting the apparatus cool, the flask was dried for one hour at 105 degrees Celsius. The oil and flask were weighed together after cooling. The following equation was used to compute the percent oil content: -

$$\%\ oil\ =\ \{Wt.of\ flask\ +\ oil\ -\ Wt.of\ flask\ /\ Wt\ of\ flask\ +\ seed\ -\ Wt.of\ flask\}\ x\ 100$$

Kjeldhal technique was used to detect nitrogen and protein content in the Sunflower achene (Bremner, 1964). The formula used to compute the percentage of crude protein is as given below:

$$\%\ crude\ protein = \{\frac{(\text{Titration of a sample } - \text{Titration blank})\ Normality}{100}\text{Weight of the sample}\}\ x\ 14\ x\ 6.25\ x\ 100$$

RESULTS AND DISCUSSION

Number of plants at maturity: Higher crop yields are ultimately the result of good crop stand, which is ensured by having an ideal plant population per unit area. Different nitrogen application methods and sowing techniques did not significantly affected plant

population at harvest. However, plant population varied from 73 to 74 (Table 1). The non-significant effect of different nitrogen application methods and sowing techniques on plant population was due to maintenance of uniform plant stand by thinning in all treated plots. The researcher such as (Memon *et al.*,2011) found that plant population was not significantly affected by the techniques of seeding.

Table 1: Effect on number of plants (per plot) of sunflower:

Treatment		Nitrogen application method			
		F_1(Fertigation)	F_2 (Band placement)	F_3 (Side dressing)	Mean
Sowing techniqu	S_1(Flat sowing)	73.3	73.7	74.0	73. 7
	S_2(Ridge sowing)	73.0	73.7	73.3	73.3
	S_3(Bed sowing)	73.3	73.7	74.0	73.7
Mean		73.2	73.7	73.8	

Height of plant (cm): The highest possible height illustrates how an agricultural plant grows. It is dependent upon the genetic composition of the species and the conditions in which the plant grows. Table 2 provides information on plant height measured at maturity. Significant results were obtained regarding the interaction between nitrogen application strategies (S x F) and sowing techniques. Plots where sunflower was seeded on beds and nitrogen was provided by fertigation technique (F1S3) showed the highest plant height (174.33 cm), which was comparable to F1S2. The treatment where the crop was seeded flatly and nitrogen was given by side dressing method (F3S1), which was statistically equivalent to F2S1, yielded the lowest plant height (165.00 cm). Since nitrogen is necessary for a plant's vegetative development, an increase in plant height with an increase in nitrogen availability may be explained. These outcomes are consistent with the research conducted by Sarker *et al*. (2022).

Table 2: Effect on plant height (cm) of sunflower

Treatment		Nitrogen application method			
		F_1 Fertigation)	F_2 (Band placement)	F_3 (Side dressing)	Mean
Sowing techniqu	S_1(Flat sowing)	168.00 de	166.67 ef	165.00 f	166.56 c
	S_2(Ridge sowing)	173.00 ab	167.67 de	168.00 de	169.56 b
	S_3(Bed sowing)	174.33 a	171.00 bc	170.00 cd	171.78 a
Mean		171.78 a	168.48 b	167.67 b	

At 5% probabilities, means that don't have the same letters differ significantly.
LSD for interaction (S x F) =2.3346; LSD for F =1.3479; and LSD for S = 1.4024

Diameter of stem (cm): The rapid growth of the sunflower stem indicates the plant's capacity for further development. Table 3 provides information on the stem diameter measured at maturity. Significant results were also obtained regarding the interaction between nitrogen application strategies (S x F) and sowing techniques. Plots where sunflower was seeded on beds and nitrogen was provided by fertigation technique (F1S3) showed the maximum stem diameter (3.70 cm), which was comparable to F1S2. In the treatment where the crop was flat-sown and nitrogen was given by side dressing, the lowest stem diameter (1.47 cm) was measured (F3S1). These results concur with the findings of Seabra *et al*., (2022).

Table 3: Effect on stem diameter (cm) of sunflower

Treatment		Nitrogen application method			
		F_1 Fertigation)	F_2 (Band placement)	F_3 (Side dressing)	Mean
Sowing technique	S_1(Flat sowing)	3.37 b	1.63 e	1.47 f	2.16 c
	S_2(Ridge sowing)	3.61 a	1.81 d	2.67 c	2.69 b
	S_3(Bed sowing)	3.70 a	3.41 b	3.38 b	3.50 a
Mean		3.56 a	3.56 a	2.50 b	2.30 c

At 5% probability, means that don't have the same letters differ significantly. LSD for interaction (S x F) = 0.1573, LSD for F = 0.0908, and LSD for S = 0.0692

Diameter of Head (cm): One crucial factor in sunflower production is head diameter. It is primarily a hereditary trait, however the environment in which the plant is cultivated also has an impact. In table 4, information about head diameter is displayed. Significant results were also obtained regarding the interaction between nitrogen application strategies (S x F) and sowing techniques. Plots where sunflower was seeded on beds and nitrogen was provided by fertigation technique (F1S3) showed the maximum head diameter (23.13 cm), which was comparable to F1S2, F2S3, and F3S3. Plots where sunflower was flat-sown and nitrogen was treated by side dressing technique (F3S1) had the lowest head diameter (11.53 cm), which was statistically equivalent to F2S1.

Table 4: Effect on head diameter (cm) of sunflower

Treatment		Nitrogen application method			
		F_1(Fertigation)	F_2 (Band placement)	F_3 (Side dressing)	Mean
Sowing techniqu	S_1(Flat sowing)	21.07 b	13.13 de	11.53 e	15.24 b
	S_2(Ridge sowing)	23.03 a	14.17 d	18.30 c	18.50 a
	S_3(Bed sowing)	23.13 a	22.27 ab	21.93 ab	22.44 a
Mean		22.41 a	17.25 b	16.52 b	

At 5% probability, means that don't have the same letters differ significantly. LSD for interaction (S x F) = 2.0376; LSD for F = 1.1764; and LSD for S = 0.9207

Achenes per head: One significant yield factor that affects crop potential production is the amount of achenes per head. Table 5 displays the information on the quantity of achenes per head. Under various nitrogen application methods and sowing techniques, there were considerable differences in the quantity of achenes per head. Maximum number of achene per head (1237.6) was observed where sunflower was sown on beds and nitrogen was applied by fertigation method (F_1S_3) which was at par with F_1S_2. Minimum number of achenes per head (772.1) was recorded where crop was sown by flat sowing technique and nitrogen was applied by side dressing method (F_3S_1) which was statistically at par with F_2S_1. These findings concur with those of Verma *et al*., (2023), who discovered that nitrogen fertigation increased the quantity of seeds per head. Greater head diameter in sunflowers can be attributed to more achene per head

Table 5: Effect on number of achenes per head of sunflower

Treatment		Nitrogen application method			
		F_1(Fertigation)	F_2 (Band placement)	F_3 (Side dressing)	Mean
Sowing techniqu	S_1(Flat sowing)	1164.0 c	780.1 e	772.1 e	905.4 c
	S_2(Ridge sowing)	1230.4 ab	809.9 d	1161.8 c	1067.4 b
	S_3(Bed sowing)	1237.6 a	1219.0 b	1173.3 c	1210.0 a
Mean		1210.7 a	1035.7 b	936. 3 c	

At 5% probability, means that don't have the same letters differ significantly. LSD for F = 9.4338, LSD for interaction (S x F) = 16.340, and LSD for S = 18.625.

Thousand-achene weight (g): The weight of the 1000 achenes is a crucial yield factor for sunflowers that greatly influences their ultimate output. Table 6 presents the results on 1000-achene weight as influenced by different nitrogen delivery techniques and planting techniques. The weight of 1000 achene is greatly impacted by the various nitrogen delivery techniques and planting methods,

Table 6: Effect on 1000-achene weight (g) of sunflower

Treatment		Nitrogen application method			
		F_1(Fertigation)	F_2 (Band placement)	F_3 (Side dressing)	Mean
Sowing techniq	S_1(Flat sowing)	63.80 c	59.57 e	57.35 f	60.24 c
	S_2(Ridge sowing)	67.82 a	61.17 d	61.58 d	63.53 b
	S_3(Bed sowing)	68.17 a	65.95 b	64.66 c	66.26 a
Mean		66.60 a	62.23 b	61.20 c	

At 5% probability, means that don't have the same letters differ significantly. LSD for interaction (S x F) = 0.9229, LSD for F = 0.5328, and LSD for S = 1.0838

Maximum thousand achene weight (68.17 g) was observed in plots where crop was sown on beds and nitrogen was fertigated (F_1S_3) which was at par with F_1S_2. The minimum thousand achene weight (57.35 g) was recorded in treatment where crop was flat sown and nitrogen was applied by side dressing (F_3S_1). Increase in 1000-achene weight might be due to more availability of nitrogen that is attributed to better plant growth and more photosynthates accumulation in achenes. These results are in agreement with those of Zheng *et al.,* (2023) who found maximum thousand grain weight in bed sowing and minimum thousand grain weight in flat sowing technique. Such findings are also reported by Zafar *et al.,* (2013).

Biological yield (t ha^{-1}): A crucial metric for assessing a crop's photosynthetic efficiency is biological yield. Table 7 provides information about the biological yield measured at maturity. When applying nitrogen in different ways in various sowing methods, the biological output varies dramatically. Highest biological yield (10.92 tha^{-1}) was observed in treatments where sunflower was sown on beds and nitrogen was applied by fertigation method (F_1S_3) which was statistically at par with F_1S_2, $F_2S_3$and F_3S_3 The minimum biological yield (9.21 t ha^{-1}) was

recorded where crop was flat sown and nitrogen was applied by side dressing method (F_3S_1). Increase in biological yield is may be due to that in fertigation method and bed sowing treatment, nutrient uptake, fertilizer utilization and its assimilation is increased that resulted in increase in plant height and head diameter. These results are in accordance to the findings of Zheng *et al.,* (2023) who reported that bed sowing of sunflower produced highest biological yield.

Table 7: Effect on biological yield (t ha^{-1}) of sunflower

Treatment		Nitrogen application method			
		F_1(Fertigation)	F_2 (Band placement)	F_3 (Side dressing)	Mean
Sowing techniqu	S_1(Flat sowing)	10.27 b	9.66 c	9.21 d	9.71 c
	S_2(Ridge sowing)	10.83 a	9.73 c	10.21 b	10.26 b
	S_3(Bed sowing)	10.92 a	10.85 a	10.78 a	10.85 a
Mean		10.67 a	0.08 b	10.07 b	

Means not sharing the same letters differ significantly at 5% probability: LSD for S = 0.0985, LSD for F = 0.1574, LSD (S x F) = 0.2727 for interaction

Achene yield (t ha^{-1}): The overall impacts of several yield components, such as plant density, head diameter, number of achenes per head, and 1000-achene weight, determine the final achene yield. Achene yield data is provided in Table 8.

Achene yield is significantly impacted by seeding techniques and nitrogen application methods. Highest achene yield (3.22 t ha^{-1}) was observed in treatment in which nitrogen was applied through fertigation and crop was sown by flat sown technique (F_1S_3). The minimum achene yield (2.22 t.ha^{-1}) was recorded where nitrogen was side dressed and crop was sown by flat sown technique (F_3S_1). It may be attributed to the reason that efficiency of fertilizer increased with the availability of moisture. Availability of soil moisture for plant growth and development is enhanced in fertigation method as it is necessary to make full use of resources like fertilizer and light. These results are in conformity with findings of Zheng *et al.,* (2023).

Table 8: Effect on achene yield (t ha^{-1}) of sunflower

Treatment		Nitrogen application method			
		F_1(Fertigation)	F_2 (Band placement)	F_3 (Side dressing)	Mean
Sowing techniqu	S_1(Flat sowing)	2.77 d	2.34 e	2.22 f	2.44 c
	S_2(Ridge sowing)	3.05 c	2.73 d	2.76 d	2.85 b
	S_3(Bed sowing)	3.22 a	3.18 b	3.16 b	3.19 a
Mean		3.01 a	2.75 b	2.71 b	

At 5% probability, means that don't have the same letters differ significantly. LSD for F = 0.193, LSD for interaction (S x F) = 0.0335, and LSD for S = 0.0162

Harvest Index (%): An essential metric for assessing a crop's ability to efficiently convert photosynthetic increase into commercial produce is the harvest index. Table 9 provides the harvest index statistics. Harvest index is significantly differed among varying nitrogen application methods and sowing techniques. Maximum harvest index (29.48%) was observed in treatment where crop was sown on beds and nitrogen was applied by fertigation method (F_1S_3) which was at par with F_2S_3 and F_3S_3. The minimum harvest index (24.10%) was recorded in treatment where sunflower was flat sown and nitrogen was applied through side dressing method (F_3S_1) and it was statistically at par with F_2S_1. These results are in line with the findings of Zheng *et al.,* (2023).

Table 9: Effect on harvest index (%) of sunflower

Treatment		Nitrogen application method			
		F_1(Fertigation)	F_2 (Band placement)	F_3 (Side dressing)	Mean
Sowing techniqu	S1(Flat sowing)	26.98 c	24.21 d	24.10 d	25.01c
	S2(Ridge sowing)	28.20 b	28.08 b	27.04 c	27.77 b
	S3(Bed sowing)	29.48 a	29.31 a	29.31 a	29.36 a
Mean		28.22 a	27.20 b	26.82 b	

At 5% probability, means that don't have the same letters differ significantly. LSD for interaction (S x F) = 0.6803, LSD for F = 0.3928, and LSD for S = 0.1590

Achene oil contents (%): The amount of achene oil in sunflower seeds determines its quality. Table 10 provides information on the achene oil contents recorded at maturity. The oil contents exhibit notable variations by applying nitrogen using different techniques and planting of crop in different methods. Maximum achene oil contents (41.78 %) were observed where nitrogen was side dressed and flat sowing technique was adopted for crop sowing (F_3S_1) which was at par with F_2S_1 and F_2S_2. The minimum achene oil contents (39.33 %) were recorded in the treatment where nitrogen was fertigated and bed sowing technique was adopted for crop sowing (F_1S_3) which was statistically at par with F_1S_2 and F_2S_3. These results are in accordance with Zheng *et al.,* (2023) who reported that increase in nitrogen contents causes a

decrease in oil contents. Reduction in achene oil contents with increasing nitrogen contents attributed to the formation of more amino acids rather than fatty acids in seed

Table 10: Effect of on oil contents (%) of sunflower

Treatment		Nitrogen application method			
		F_1(Fertigation)	F_2 (Band placement)	F_3 (Side dressing)	Mean
Sowing techniqu	S_1(Flat sowing)	40.68 b	41.72 a	41.78 a	41.39 a
	S_2(Ridge sowing)	39.44 c	41.17 ab	40.77 b	40.46 b
	S_3(Bed sowing)	39.33 c	39.58 c	40.45 b	39.79 c
Mean		39.81 b	40.83 a	41.00 a	

At 5% probability, means that don't have the same letters differ significantly. LSD for interaction (S x F) = 0.6282, LSD for F = 0.3627, and LSD for S = 0.6492

Achene protein contents (%): The amount of protein in oil seeds also affects their quality. Table 11 provides information on the protein contents reported at maturity. There are notable variations in protein compositions of achene after applying nitrogen through different techniques and varying sowing methods. Maximum protein contents (29.03 %) were observed in the treatment in which nitrogen was applied by fertigation and crop was sown on bed (F_1S_3) which was statistically at par with F_1S_2. The minimum protein contents (21.23 %) were recorded where nitrogen was applied through side dressing method and crop was flat sown (F_3S_1) followed by F_2S_1. These findings are in line with those of Zheng *et al.,* (2023).

Table 11: Effect on protein contents (%) of sunflower

Treatment		Nitrogen application method			
		F_1(Fertigation)	F_2 (Band placement)	F_3 (Side dressing)	Mean
Sowing techniqu	S_1(Flat sowing)	26.53 b	23.00 cd	21.23 d	23.59 c
	S_2(Ridge sowing)	27.50 ab	23.70 c	25.83 b	25.68 b
	S_3(Bed sowing)	29.03 a	26.83 b	26.77 b	27.54 a
Mean		27.69 a	24.51 b	24.61 b	

At 5% probability, means that don't have the same letters differ significantly. LSD for interaction (S x F) = 1.9361, LSD for F = 1.1178, and LSD for S = 0.9527

CONCLUSION

On the basis of above mentioned results, it was summarized that sunflower exhibited maximum agronomic parameter including plant height, stem diameter, head diameter, achenes per head, 1000-achene weight, highest biological & achene yield and harvest index alongwith maximum protein contents in treatment where nitrogen was applied by fertigation method and crop was sown on beds. While maximum achene oil contents were observed where nitrogen was side dressed and flat sowing technique was adopted for crop sowing. So, it is recommended that sunflower may be planted on ridges by applying nitrogen as fertigation to achieve maximum productivity.

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