Asian Research Journal of Agriculture

Volume 17, Issue 1, Page 22-32, 2024; Article no.ARJA.112590
ISSN: 2456-561X

Comparative Evaluation of Nano Urea Versus Conventional Urea for Nitrogen Management in Rainfed Sunflower (*Helianthus annuus* L.) Cultivation in Acid Sandy Loam Soils of Assam.

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Authors' contributions

This work was carried out in collaboration among all authors. Authors JK, BB, NB and HC designed the study. The author SD conducted the field and laboratory work and generated data. Author JK performed the statistical analysis and wrote the protocol. Authors SD and BB wrote the first draft of the manuscript. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/ARJA/2024/v17i1407

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/112590

Original Research Article

Received: 25/11/2023
Accepted: 31/01/2024
Published: 03/02/2024

ABSTRACT

A field experiment was conducted during *rabi*, 2021-22 at the experimental plot of the Department of Agronomy, Biswanath College of Agriculture (BNCA), Assam Agricultural University (AAU), Biswanath Chariali, Assam having geographic coordinates 26°43'30'' N and 93°08'08'' E to assess nitrogen management in Sunflower (*Helianthus annuus* L.) with conventional and nano urea under

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rainfed farming situations in the North Bank Plain Zone of Assam. The experiment confined to 10 treatments in Randomized Block Design (RBD) viz., T_1: Control (No Nitrogen), T_2: Soil application of 50% N, T_3: Soil application of 100% N (RD), T_4: 3 foliar applications of 0.6% nano urea, T_5: Soil application of 50% N + 2 foliar application of 1% conventional urea, T_6: Soil application of 50% N + 2 foliar application of 2% conventional urea, T_7: Soil application of 50% N + 2 foliar application of 3% conventional urea, T_8: Soil application of 50% N + 2 foliar application of 0.2% nano urea, T_9: Soil application of 50% N + 2 foliar application of 0.4% nano urea, T_{10}: Soil application of 50% N + 2 foliar application of 0.6% nano urea. Results revealed that there was no significant effect on the seedling emergence percentage due to different nitrogen management treatments. The highest plant height (84 cm) and maximum number of leaves (33) were found in T_{10}. T_9 showed the maximum values of Relative Leaf Water Content (RLWC) (71%), leaf area index (LAI) (3.2 and 4.2 at 60 and 90 DAS), chlorophyll content index (30 DAS) and head diameter (16.70 cm). For most of the growth and phenological parameters, T_9 and T_{10} were at par with each other. T_1 (no nitrogen) was the earliest to complete its life cycle which is reflected in 50% heading (65 days) and days to maturity (97 days). Dry matter accumulation varied at different time intervals, initially, it was highest in T_3 but later T_9 and T_{10} showed the maximum values. In terms of seed yield, test weight and chaffy grain percentage (%), T_9 showed the best results: (1505 kg/ha), (54 g/1000 seeds) and (20%) respectively, followed by T_{10}. Whereas the highest stover yield was recorded in T_{10}. The highest Benefit to Cost ratio (B:C ratio of 1.60) was obtained in the T_9.

Keywords: Nitrogen management; sunflower; nano urea; rainfed farming.

1. INTRODUCTION

Sunflower (*Helianthus annuus* L.) is one of the most important high-quality oilseed crops under the family Compositae (*Asteraceae*) widely cultivated worldwide. This annual herbaceous plant is tall and erect, has no branches and ends in a capitulum. The outer blossoms are known as ray flowers because they resemble petals. The inner spiraling arrangements make up the disc flowers. Sunflower crop was introduced to India in 1969 as a decorative crop and as a complement to oilseed crops. In India, commercial sunflower farming first got underway in 1972–1973 [1]. Sunflower is ranked fourth in terms of the world's largest oil-seed crop. The crop has greater adaptability in many agro-climatic zones and soil types due to its short life cycle, as well as its insensitivity to light and heat. The seed of sunflower contains 45–50% high-quality oil, and the oil cake has greater protein content (40–44%) and balanced amino acids, making it suitable for use as cattle and poultry feed [2]. An optimum proportion of saturated and polyunsaturated fatty acids can be found in sunflower oil. When comparing several vegetable oils, Ryland in 2003 discovered that sunflower oil was the healthiest because of its high oleic acid concentration [3]. The oil is excellent for lowering high serum cholesterol levels since it is abundant in linoleic fatty acid (66%) and other essential fatty acids. It contains a good amount of vitamins A, C, D, E and folic acid. In terms of heavy metal phytoremediation, it is one of the plants that has been studied the most [4]. For the production of sunflowers, nitrogen is a vital and constant plant nutrient [5] that is needed in higher concentrations than other plant nutrients [6]. Nitrogen mainly promotes the rapid development of roots and leaves, as well as the synthesis of chlorophyll, which in turn enhances biomass accumulation and yield characteristics [7-9]. To satisfy the varying nitrogen demands of crops, ordinary urea is often used as a nitrogen (N) fertilizer [10] supplied during critical development phases [11]. However, because of the quick release of nitrogen from common urea, denitrification, nitrate leaching, and ammonia volatilization cause the loss of one-fourth of the nitrogen provided by common urea [12]. The foliar application solves the problem of nutrient leaching in soil. Owing to the risk of increased leaching of conventional urea fertilizer and groundwater pollution, it is advised to switch to nano-urea instead of conventional fertilizers, especially in sandy soils [13]. One such revolutionary alternative form of fertilizer is the Nano Urea developed and Patented by IFFCO. Only IFFCO Nano Urea has been authorized by the Indian government and is listed in the Fertilizer Control Order (FCO). At least 1 bag of urea can be successfully replaced by the application of 1 bottle of nano urea. Nano Urea readily enters through stomata and other pores when sprayed on leaves and is taken up by plant cells [14]. Nano urea liquid particles are 20 to 50 nanometers in size, and it has a thousand times more surface area to volume than traditional granular urea [15]. The availability of Nano Urea to crops has increased by more than 80% due to its small size [16].

2. MATERIALS AND METHODS

The field experiment was conducted in the PG experimental field of the Department of Agronomy, BNCA, AAU, Biswanath Chariali, Assam having geographic coordinates 26^{0}43'30" N and 93^{0}08'08"E during the *rabi* season of 2021-22. The experiment consisted of 10 treatments which were laid out in a Simple Randomized Block Design with 3 replications consisting of a total of 30 plots of (5x5) m^2 size each with a net area of 750 m^2 and gross area of 1062 m^2. Treatment details are presented in Table 1. The sunflower NSFH-1001 (Sunlight) variety was taken for the experiment to assess its performance under *rabi* season in rainfed upland conditions of Assam. A dose of 70:60:40 N: P_2O_5:K_2O kg ha^{-1} was applied. Full doses of phosphorus and potash and respective treatment doses of nitrogen were applied to the lines before sowing. The soil reaction of the experimental plot was extremely acid (pH 4.20) in nature, sandy loam in texture, medium in organic carbon (0.67%), low in available N (250.88 kg ha^{-1}) with medium available P_2O_5 (33.74 kg ha^{-1}) and K_2O (187.80 kg ha^{-1}). A photograph of the experimental plot is presented in Fig. 1.

2.1 Preparation of the Field

The experimental plot was ploughed by a tractor-drawn disc plough and subsequently, one harrowing was done followed by levelling and final preparation by a tractor-drawn rotavator. After the preparatory tillage, the field was laid out in 30 plots of the same size as per the layout plan and the treatment combinations were applied randomly as per the statistical design.

2.2 Application of Fertilizers

The fertilizers were applied in each plot according to the treatment. Different doses of nitrogenous fertilizers (urea) and full doses of phosphatic (single super phosphate) and potassic (murate of potash) fertilizers were applied as uniformly as possible before sowing. The recommended dose of N:P: K of 70:60:40 kg/ha was followed for sunflower.

2.3 Sowing of Seeds

The seeds were sown in a line after the preparation of furrows by using *a desi* plough at 60 cm row-to-row spacing and seeds were placed 20 cm apart manually in the plots. The seed rate was 10 kg ha^{-1} and after sowing the soil covering was done and pressed slightly to have good contact with the soil.

2.4 Irrigation

No irrigation was given as it was a rainfed cultivation. The crops were allowed to grow with the residual moisture content of the soil.

2.5 Intercultural Operation

Two hand weeding and earthing up were done at 45 DAS and 90 DAS.

2.6 Foliar Application of Nitrogen

Foliar spray of conventional urea (1%, 2%, 3%) and nano urea (0.2%, 0.4%, 0.6%) was done at 30 DAS, 60 DAS and 90 DAS according to the respective treatments.

2.7 Harvesting

Harvesting of sunflower heads was done when the sunflower had died back, the seeds became plump and loose and the back of the capitulum (head) became brown. The sunflower variety grown in the experiment was harvested between 100 -110 DAS. The stalk below the mature head was cut with a sharp knife or pruners and placed in the sun. The harvested heads were picked by hand into separate bags in which labels were tagged showing replication and treatment numbers. Cutting was done in the afternoon hours when the moisture content of the heads was low and the ambient temperature was high. After completion of harvesting, the heads were sun-dried for 3-5 days in outdoors. Threshing was done and yield attributes were recorded. After 7 days of harvesting, the plants were uprooted, weighed and recorded for stover yield estimation.

2.8 Observations Recorded

Seed germination %: Seed germination % was tested in the lab keeping the seeds on wet filter paper in Patri dish. Seedling emergence % up to 10 DAS was recorded in the field condition.

Plant height: The plant height was from the base of the plant at ground level up to the top.

Number of leaves per plant: From each plot five plants were selected randomly leaving the border rows of the plot and the number of leaves was recorded.

Relative leaf water content:

$$RLWC = \frac{\text{Fresh weight} - \text{Dry weight}}{\text{Fully turgid weight} - \text{Dry weight}} \times 100 \ldots (1)$$

Leaf Area Index (LAI):

$$LAI = \frac{\text{Total leaf area of a plant}}{\text{Ground area occupied by the plant}} \ldots\ldots\ldots\ldots (2)$$

Plant dry matter accumulation (g plant^{-1}): The fresh plant samples were weighed and oven-dried for a few days until the samples were left with no moisture.

Days to 50% heading: The total number of days from sowing to the first emergence of heads in each plot, recorded until 50% of the plant population in each plot showed head emergence.

Days to maturity: The total number of days taken from the date of sowing till the date of maturity was recorded in each plot.

Head diameter: The head diameter was measured in the mature heads before harvesting. It is measured in centimetres and determines the number of seeds per head of the plant. The more the head diameter, the more will be the yield.

Final plant population (no. m^{-2}): From each plot, the number of plants per m^2 was recorded and the average of the recorded data was taken for statistical analysis.

Weight of seeds per head (g head^{-1}): Five harvested heads were selected from each plot, their seeds were threshed out and weighed using an electric balance very gently and the mean value of the weight of seeds per head was calculated.

Percent of Chaffy seeds per head: Five heads were selected from each plot, their seeds were mixed and 100 seeds were selected randomly and soaked in water for 5 hours. The number of floating seeds was counted and thus chaffy seeds percentage was calculated.

Test weight (g): After threshing, 1000 seeds per plot were selected and their weight was measured in the electric weighing balance.

Seed yield per plant: Five harvested heads were selected from each plot; their seeds were threshed out and weighed using electric balance very gently and the mean value of the seed yield (grams) per plant was calculated.

Seed yield (kg/ha): Heads were harvested from each plant, seed yield per plant was calculated and then it was converted into kilograms per hectare.

Stover yield (kg/ha): After harvesting heads, the green plants were allowed to stand in the field for a week. By this time all the plants were uprooted from the ground and the total weight of all plants from each plot was taken. Per plot yields were then converted to kilogram per hectare.

Harvest Index (%):

Harvest index (%) = Economic yield (kg/ha))/Total biological yield (kg/ha) *100 (3)

Table 1. Treatment details of the experiment

Treatment No.	Treatment details
T_1	Control (No Nitrogen),
T_2	Soil application of 50% N
T_3	Soil application of 100% N (Recommended Dose)
T_4	3 foliar application of 0.6% nano urea
T_5	Soil application of 50% N + 2 foliar application of 1% conventional urea
T_6	Soil application of 50% N + 2 foliar application of 2% conventional urea
T_7	Soil application of 50% N + 2 foliar application of 3% conventional urea
T_8	Soil application of 50% N + 2 foliar application of 0.2% nano urea
T_9	Soil application of 50% N + 2 foliar application of 0.4% nano urea
T_{10}	T_{10}: Soil application of 50% N + 2 foliar application of 0.6% nano urea.

Fig. 1. Experimental plot

2.9 Economic Analysis

Cost of cultivation (Rs. ha^{-1}), Gross return (Rs. ha^{-1}), Net Return (Rs. ha^{-1}) and Benefit-Cost ratio were analyzed after harvesting of the crop.

3. RESULTS AND DISCUSSION

Seed germination percentage was found to be 61%. The effect of treatments for seedling emergence was found to be non-significant at 10 DAS.

3.1 Plant Height

The effect of nitrogen treatments on plant height (Table 2) was found to be significant in the entire crop growth stages except for at 20 DAS. This may be due to the slow initial growth of the crop and a similar amount of soil nitrogen application at the time of sowing. Response of sunflower growth to nitrogen application could be attributed to the fact that nitrogen enhances growth and vigour in plants (in terms of height and leaf number). An increased number of nodes is present in longer stems, which in turn produces a greater number of leaves. Earlier workers have also reported similar findings [17].

3.2 Number of Leaves Per Plant

The data on the number of leaves per plant measured at 30 DAS, 60 DAS and 90 DAS are presented in Table 2. The effect of treatments on the number of leaves per plant of sunflower was non-significant at 30 and 60 DAS. However, the effect of treatments was found to be statistically significant at 90 DAS. The highest number of leaves per plant was found in plants treated with Soil application of 50% N + 2 foliar application of 0.6% nano urea (33.00 at 90 DAS). The lowest value of the number of leaves per plant was observed in plants in the control treatment (27.33 at 90 DAS). Applications of nitrogen (N) fertilizer increased plant height and leaf count (growth parameters) to the maximum levels of N. When growth-friendly circumstances and adequate N sources are met, proteins are synthesized from the produced carbs. As a result, the vegetative component of the plant produces less carbohydrates, more protoplasm is created, and because the protoplasm is highly hydrated, a more succulent plant is produced. On the other hand, carbs are deposited in vegetative cells to thicken them when N levels are low [18,19]. Therefore, an increase in N application is consistent with an increase in crop growth.

3.3 Relative Leaf Water Content

The data on relative leaf water content are presented in Table 3. The effect of treatments on the relative leaf water content was found to be significant. The highest RLWC was found in the treatment with Soil application of 50% N + 2 foliar application of 0.4% nano urea (71.00 % at 60 DAS) and the lowest RLWC was found in the control treatment (64%). Similar results was reported where water stress considerably lowered all of the essential characteristics of Kentucky bluegrass, but proper nutritional management treatment produced the best compensatory performance under drought, reducing its adversity to some extent [20]. Thus, these results may be taken into consideration while developing good feasible and cost-effective solutions for similar environmental conditions.

3.4 Leaf Area Index (LAI)

The data on the Leaf Area Index of sunflowers as influenced by treatments are presented in Table 3. The effect of treatments measured was found to be significant in terms of the Leaf Area Index (LAI). The maximum Leaf Area Index (3.20 at 60 DAS and 4.20 at 90 DAS) was found where soil application of 50% N + 2 foliar application of 0.4 % nano urea was given and it was statistically higher than the control plot where no nitrogen was given. The results were also in line with the report of Giannoulis, *et al*., (2008) who reported an increase in LAI with an increase in N fertilization [21]. When compared to other treatments, the value for LAI in N-omitted and lesser N plots was much lower. After crop emergence and throughout the whole crop cycle, all treatments produced more dry matter until the crop was mature. The higher number of leaves is reflected in the case of leaf area index (LAI) during the crop growth period [22].

3.5 Chlorophyll Content Index

The effect of treatments was found to be significant in terms of the Chlorophyll Content Index as shown in Table 3. The highest value (71.00) was recorded under soil application of 50% N + 2 foliar applications of 0.4 % nano urea treatment which was statistically higher than the lowest value of chlorophyll content of the control plot (64.00). This may be due to the role of nitrogen, which is essential for the synthesis of RNA, DNA, and energy components like ATP, as well as the enzyme partners, which was the cause of the increase in the chlorophyll content in plant leaves. Additionally, nitrogen contributes to the synthesis of several vitamins and enzymes. The chlorophyll, which is primarily involved in the process of representing carbon and is the substance responsible for the photosynthesis process in the plant's leaves, is what gives the green parts of the plant their dark green colour. It also plays a significant role in several physiological processes [23]. The growth phase may have been prolonged and plant height may have risen as a result of high NPK doses [24] Plants with superior N availability had substantially larger sunflower heights and shoot dry matters than plants with lower N availability [25]. With the maximal dose, Yadav, *et al*., (2009) also noted the maximum plant height and other growth characteristics [26].

3.6 Plant Dry Matter at 20 Days Interval

The data on dry matter accumulation (g plant^{-1}) of sunflower as influenced by different Nitrogen treatments are presented in Table 4. Statistically, the highest dry matter per plant was found in the treatment with soil application of 50% N + 2 foliar application of 0.4% nano urea, as well as in the treatment with soil application of 50% N + 2 foliar application of 0.6% nano urea (at par). The lowest dry matter/ plant was observed in the control- no nitrogen treatment.

3.7 Days to 50% Heading

The data on days to 50% heading of sunflower as influenced by different Nitrogen treatments are presented in Table 5. The effect of treatments was found to be significant on days to 50% heading. The highest value was found in the treatment with Soil application of 50% N + 2 foliar application of 0.6% nano urea (78 days) and the lowest value was found in the control treatment (65 days) showing a relatively early maturity in the treatments with low nitrogen input as compared to others.

3.8 Days to Maturity

The data on the days to maturity of sunflowers, as influenced by different Nitrogen treatments, are presented in Table 5. The effect of treatments on the days to maturity of sunflower was found to be significant. The highest value was found in the treatment with Soil application of 50% N + 2 foliar application of 0.6% nano urea (110 days) and the lowest value was found in the control treatment (97 days).

Table 2. Effect of treatments on plant height (cm) of sunflower at different stages

Treatments	Plant height (cm)					No. of leaves		
	20 DAS	40 DAS	60 DAS	80 DAS	At harvest	30 DAS	60 DAS	90 DAS
T_1	9.00	20.00	35.33	60.33	68.00	12.67	22.20	27.33
T_2	11.00	24.67	37.00	63.00	71.00	13.67	22.33	28.20
T_3	12.20	25.00	40.00	66.00	74.67	14.85	23.67	29.80
T_4	11.00	21.73	37.67	63.00	72.00	13.33	22.20	29.00
T_5	10.87	24.44	39.33	66.00	74.00	14.43	23.20	30.70
T_6	10.80	24.22	41.33	73.33	80.00	14.07	23.73	31.13
T_7	11.27	24.32	43.67	69.00	76.00	13.67	23.63	30.13
T_8	11.00	25.00	47.77	73.89	82.00	14.00	23.57	30.40
T_9	10.97	25.33	49.33	75.33	84.00	13.53	23.93	32.67
T_{10}	10.47	25.67	50.67	75.67	83.17	14.33	25.00	33.00
SE(d)	0.73	1.28	3.24	1.50	0.95	0.80	1.37	0.96
CD (p=0.05)	NS	2.63	6.63	3.07	1.94	NS	NS	1.97
CV (%)	8.26	6.54	9.41	2.68	1.52	7.11	7.18	3.90

Table 3. Effect of treatments on LAI, chlorophyll content index and RLWC% of sunflower

Treatments	LAI		Chl content index	RLWC (%)
	60 DAS	90 DAS		
T_1	2.80	3.40	64.00	25.00
T_2	2.85	3.50	65.00	26.00
T_3	3.04	3.90	67.00	28.00
T_4	2.91	3.60	64.33	26.50
T_5	3.00	3.80	66.00	27.50
T_6	3.06	3.95	68.00	28.50
T_7	2.95	3.70	65.00	27.00
T_8	3.12	4.00	69.67	29.00
T_9	3.20	4.20	71.00	30.00
T_{10}	3.16	4.10	70.33	29.50
SE(d)	0.28	0.09	0.90	0.85
C.D (p=0.05)	NS	0.18	1.84	1.73
CV (%)	11.32	2.87	1.65	3.75

Table 4. Effect of treatments on plant dry matter (g) at 20-day intervals of sunflower

Treatments	Plant dry matter (g)/ plant				
	20 DAS	40 DAS	60 DAS	80 DAS	100 DAS
T_1	4.97	7.09	13.94	31.51	44.37
T_2	5.50	8.07	15.17	34.65	49.67
T_3	5.77	11.20	17.28	40.73	54.00
T_4	5.00	9.50	14.30	33.03	46.33
T_5	5.63	10.57	16.74	38.11	50.67
T_6	5.53	10.67	19.17	42.43	57.67
T_7	5.60	8.37	17.27	39.13	51.67
T_8	5.63	10.43	18.67	42.43	57.67
T_9	5.67	11.00	20.00	44.84	61.67
T_{10}	5.57	11.13	20.33	45.14	59.69
SE(d)	0.62	0.46	0.56	0.61	0.67
CD (p=0.05)	NS	0.93	1.15	1.25	1.37
CV (%)	13.76	5.69	3.99	1.90	1.53

Table 5. Effect of treatments on days to 50% heading, days to maturity and head diameter of sunflower

Treatments	Days to 50% heading	Days to maturity	Head diameter (cm)
T_1	65.00	97.00	11.00
T_2	67.00	99.00	12.00
T_3	70.00	102.00	14.07
T_4	77.00	109.00	11.93
T_5	69.00	101.00	13.37
T_6	71.67	103.67	14.73
T_7	74.00	106.00	12.83
T_8	75.00	107.00	15.53
T_9	76.00	108.00	16.70
T_{10}	78.00	110.00	15.90
SE(d)	2.51	2.51	0.54
C.D (p=0.05)	5.13	5.13	1.10
CV (%)	4.25	2.94	4.77

3.9 Head Diameter (cm)

The data on the head diameter of sunflowers as influenced by different Nitrogen treatments are presented in Table 5. The effect of treatments on the head diameter of sunflowers was found to be significant. The highest value was found in the treatment with Soil application of 50% N + 2 foliar application of 0.4% nano urea (16.70 cm) and the lowest value was found in the control treatment (11 cm). This may be because a higher dose of N leads to better vigorous growth of the plants, more accumulation of dry matter and thus bigger sunflower heads. Excessive N is not so beneficial for the reproductive growth of the plant parts. This may be the reason for better results of treatment 9 as compared to treatment 10. As nutrition has an impact on heading formation. High rates of N application are known to cause heading to be delayed because vegetative tissues utilize metabolites. Therefore, it appears that the high-rate N treatments in this research spurred enough vegetative growth to postpone sunflower heading [27].

3.10 Yield Attributes

Effect of treatments on yield attributes and yield of sunflower are presented in Table 6. The treatments with Soil application of 50% N + 2 foliar application of 0.4% and 0.6% nano urea showed a significantly higher weight of seeds per head or in other words weight of seeds per plant (as there was a single head per plant) among all other treatments. And the lowest value was seen in the control – no Nitrogen treatment. This could be related to their corresponding head diameters. The bigger the head size, the more the number of seeds per head, resulting in more weight of seeds per head. This may be attributed to the general improvement in crop health and the synthesis of adequate photosynthates with increasing nitrogen availability [28]. Along with the rise in nitrogen level, chaffy grain quantity also surged, but chaffy grain percentage reduced. This might be a consequence of rising competition for photosynthates brought on by more seeds per head at higher nitrogen levels. The effect of treatments on the test weight (g) of the sunflower variety was found to be statistically significant. The highest value was found in the treatment with Soil application of 50% N + 2 foliar application of 0.4% nano urea (41.67 g) and the lowest value was found in the control treatment (38.00 g). The yield increase could be attributed to the positive response of yield attributes, i.e., head diameter and seeds/head to nitrogen application [29,30]. The highest seed yield (1505 kg/ha) was produced by the treatment with Soil application of 50% N + 2 foliar application of 0.4% nano urea whereas the highest stover yield (2950 kg/ha) was produced by the treatment with Soil application of 50% N + 2 foliar application of 0.6% nano urea. This may be attributed to the fact that the highest vegetative growth in this treatment was maximum due to the highest application of nano urea concentration along with 50% basal urea leading to the highest stover yield. The findings from this study, which show an increase in seed yield when N levels rise, are consistent with several findings [31-33]. Due to the application of increasing N rates, seed yield increased significantly, which explains why N rates had such a substantial influence on yield. Some researchers associated the N requirement with available water to the plant [33-35]. The Harvest index was found to be significantly higher in treatments with control check nitrogen

Table 6. Effect of treatments on yield attributes and yield of sunflower

Treatments	Weight of seeds per head (g)	Chaffy seeds per head (%)	Test weight (g)	Seed yield (kg/ha)	Stover yield (kg/ha)	Harvest index
T_1	21.10	25.03	38.00	1055.00	1925.00	35.40
T_2	23.80	24.03	40.00	1190.00	2200.00	35.10
T_3	26.00	21.03	41.67	1300.00	2625.00	33.11
T_4	23.00	25.03	41.00	1150.00	2075.00	35.66
T_5	25.00	22.03	38.33	1250.00	2400.00	34.24
T_6	27.00	21.03	39.00	1350.00	2600.00	34.18
T_7	24.53	23.03	41.00	1226.67	2500.00	32.92
T_8	27.87	20.03	39.00	1393.33	2750.00	33.63
T_9	30.10	18.90	41.67	1505.00	2900.00	34.16
T_{10}	29.43	18.50	41.00	1471.67	2950.00	33.28
SE(d)	0.58	0.24	0.97	29.22	4.81	054
C.D(p=0.05)	1.20	0.49	1.99	59.76	9.84	1.11
CV (%)	2.78	1.34	2.97	2.78	0.24	1.95

Table 7. Economics attributes sunflower as affected by treatments

Treatments	Cost of cultivation (Rs/ha)	Gross return Rs/ha	Net return Rs/ha	B: C ratio
T_1	60930	73850	12920	1.21
T_2	61842	83300	21458	1.35
T_3	62754	91000	28246	1.45
T_4	69930	80500	10570	1.15
T5	61962	87500	25538	1.41
T6	62082	94500	32418	1.52
T7	62382	85867	23485	1.38
T8	63842	97533	33691	1.53
T9	65842	105350	39508	1.60
T10	67842	103017	35175	1.52
SE(d)	-	2045.20	2045.20	0.03
C.D (p=0.05)	-	4182.90	4182.90	0.07
CV (%)	-	2.78	9.52	2.78

and soil application with 50% N (RDF). This may be due to the availability of the lowest N in these treatments which led to relatively reduced vegetative growth and efficient seed yield, despite lower total production.

3.11 Economics studies

Economic analysis is presented in Table 7. In the present study Soil application of 50% N + 2 foliar application of 0.4% nano urea recorded the highest gross return, net return, benefit-cost ratio and economic efficiency than the other nitrogen management treatments. The highest cost of cultivation was incurred by the treatment with 3 foliar applications of 0.6% nano urea.

4. CONCLUSION

Highest production, productivity and profitability were found when nitrogen management was done in combination with soil application of 50% N + 2 foliar application of 0.4% nano urea. Thus, the sunflower yield can be maximised with higher B:C rations during *the rabi* season under the rainfed upland situation of Assam using a proper nitrogen management strategy using nano urea. Since these findings are generated only from the one year of the experiment, further investigations for more years are required to derive a valid conclusion before putting these findings for recommendations to the farming community.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Gebremedhin T, Shanwad UK, Gebremedhin W. Nutrient management in sunflower *(Helianthus annuus L.)*. LAP LAMBERT Academic Publishing; 2015.
2. Singh Z, Ghosh G, Debbarma V. Effect of Different Levels of Nitrogen, Sulphur and Foliar Application of Boron in Sunflower (*Helianthus annuus* L.). Int. J. Curr. Microbiol. App. Sci. 2017;6(10):1336-1342.
3. Ryland J. Manufacturing and food service. Sunflower Conf. Proc. Session III. Australian Oilseed Federation, Australia; 2003.
4. Kara Y, Koca S, Vaizogullar HE, Kuru A. Studying phytoremediation capacity of jojoba (S*immondsia chinensis*) and sunflower (*Helianthus annuus*) in hydroponic systems. Curr Opin Biotech. 2013;24(1):S34.
5. Schultz E, DeSutter T, Sharma L, Endres G, Ashley R, Bu H, Franzen D. Response of sunflower to nitrogen and phosphorus in North Dakota. J. Agron. 2018;110(2):685-695.
6. Ullah S, Akmal M. Response of sunflower to integrated management of nitrogen, phosphorus and sulphur. Sarhad J. Agric. 2018;34(4):740-748.
7. Mahmood MT, Maqsood M, Awan TH, Rashid S. Effect of different levels of nitrogen and intra-row plant spacing on yield and yield components of maize. Pak. J. Agric. Sci. 2001;38(2):1-2.
8. Shehzad MA, Maqsood M. Integrated nitrogen and boron fertilization improves the productivity and oil quality of sunflower grown in a calcareous soil. Turkish J. Field Crop. 2015;20(2):213-222.
9. Awais M, Wajid A, Ahmad A, Saleem M, Bashir M, Saeed U, Habib-ur-Rahman MH. Nitrogen fertilization and narrow plant spacing stimulates sunflower productivity. Turkish J. Field Crop. 2015;20 (1):99-108.
10. Yang G, Tang H, Nie Y, Zhang X. Responses of cotton growth, yield, and biomass to nitrogen split application ratio. Eur. J. Agron. 2011;35 (3):164-170
11. Awais M, Wajid A, Ahmad A, Bakhsh A. Narrow plant spacing and nitrogen application enhances sunflower (*Helianthus annuus* L.) productivity. Pak. J. Agric. Sci. 2013;50(4):689–697.
12. Beig B, Niazi MBK, Jahan Z, Hussain A, Zia MH, Mehran MT. Coating materials for slow release of nitrogen from urea fertilizer: A review. J. Plant Nutr. 2020;43 (10):1510-1533.
13. Kumar A, Ram H, Kumar S, Kumar YA, Gairola A, Kumar V, Sharma T.A Comprehensive Review of Nano-Urea vs. Conventional Urea. Int. J. Plant Soil Sci. 2023;35(23):32-40.
14. Raliya R, Saharan V, Dimkpa C, Biswas P. Nanofertilizer for precision and sustainable agriculture: current state and future perspectives. J. Agric. Food Chem. 2017; 66(26):6487-503.
15. Wu H, Li Z. Recent advances in nano-enabled agriculture for improving plant performance. Crop Journal. 2022;10:1–12.
16. Tiwari K, Kumar Y, Nayak R, Rai A, Singh J,Srivastava SSA. Nano-Urea for enhancing yield and farmers profit with potato in Uttar Pradesh. Ann.Plant Soil Res. 2021;23(4):495-500.
17. Banerjee H, Dutta, SK, Pramanik SJ, Ray K, Phonglosa A, Bhattacharyya K. Productivity and profitability of spring planted sunflower hybrid with nitrogen, phosphorus and potassium fertilizer. Ann. of Plant Soil Res. 2014;16(3):250-256.
18. Marschner H. Mineral nutrition of higher plants. 2nd (eds) Academic Press. New York. 1995;15-22.
19. Tisdale SL, Nelson WL, Beaton JD, Havlin JL. Soil fertility and fertilizers. 5th Edn. Ed; 2003.
20. Saud S, Fahad S, Yajun C, Ihsan MZ, Hammad HM, Nasim W, Amanullah AM, Alharby H, Effects of Nitrogen Supply on Water Stress and Recovery Mechanisms in Kentucky Bluegrass Plants. Front. Plant Sci. 2017;8:983.
21. Giannoulis KD, Archontoulis SV, Bastiaans L, Struik, PC, Danalatos NG. Potential growth and seed yield of sunflower as affected by sowing time, irrigation and N-fertilization in central Greece. In Proceedings of the International Conference on Agricultural Engineering/ Agriculture & Biosystems Engineering for a Sustainable World (AgEng2008), Hersonissos, Crete–Greece. 2008;23-25.
22. Ramulu, Krishna Murthy N, Jayadeva HM, Venkatesha MM, Ravi Kumar HS. Seed yield and nutrients uptake of sunflower

(*Helianthus annuus* L.) as influenced by different levels of nutrients under irrigated condition of eastern dry zone of Karnataka, India. Plant Arch. 2011;11(2):1061-1066.
23. Havlin JL, Beaton JD, Tisdale SL, Nelson WL. Soil fertility and fertilizers, An introduction to nutrient management, Upper Saddle River New Jersey; 2005.
24. Yousaf M, Bashir S, Raza H, Shah AN, Iqbal J, Arif M, Bukhari MA, Muhammad S, Hashim S, Alkahtani, J, Alwahibi MS, Hu C. Role of nitrogen and magnesium for growth, yield and nutritional quality of radish. Saudi J. Biol. Sci. 2021;28:3021–3030.
25. Cechin I, Fumis T, de F. Effect of nitrogen supply on growth and photosynthesis of sunflower plants grown in the greenhouse. Plant Sci. 2004;166:1379-1385.
26. Yadav RP, Tripathi ML, Trivedi, SK. Effect of irrigation and nutrient levels on productivity and profitability of sunflower (*Helianthus annuus*). Indian J. Agron. 2009;54(3):332-335.
27. Oyinlola EY, Ogunwole JO, Amapu IY. Response of sunflower (helianthus annuus l.) to nitrogen application in a savanna alfisol/respuesta del girasol (*Helianthus annuus* L.). Helia. 2010;33 (52):115-126.
28. Awasthi UD, Dubey SD. Effect of nitrogen and moisture conservation practices on yield, uptake, water-use efficiency and quality of linseed (*Linum usitatissimum*). *I*ndian J. Agric. Sci. 2011;81(4):383-385.
29. Rasool FU, Hassan B, Jahangir, A. Growth and yield of sunflower (*Helianthus annus* L.) as influenced by nitrogen, sulphur and farmyard manure under temperate conditions. SAARC J. Agric. 2013;11(1): 81-89.
30. Syed, TH, Ganai, MR, Ali T. Mir AH. Effect of nitrogen and sulphur fertilization on yield of and nutrient uptake by sunflower. J. Indian Soc. Soil Sci. 2006;54(3):375-376.
31. Monotti M. Il girasole: Problemi, tecnica colturale, risultati delle prove di confronto tra varietà. L'Inf. Agr. 1978;16:1413-1448.
32. Crnobarac JZ, Poljak NM, Dusanic NZ, Marinkovic BJ. The effect of fertilizers on yield and seed quality in CMS sunflower lines. In Proc. of 16th Intern. Sunfl. Conf., Fargo, ND, USA, Aug. 2004;371-376.
33. De Giorgio D, Montemurro F, Fornaro F. Four-year field experiment on nitrogen application to sunflower genotypes grown in semi-arid conditions. Helia. 2007; 30(47): 15-26.
34. Petcu G, Petcu E. Effect of cultural practices and fertilizers on sunflower yields in long term experiments. Helia**.** 2006; 29(44):135-144.
35. Lauretti D, Pieri S, Vannozzi GP, Turi M, Giovanardi R. Nitrogen fertilization in wet and dry climate. Helia. 2007;30(47):135-140.

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