

## Original Research Article

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

### 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  $26^{\circ}43'30''$  N and  $93^{\circ}08'08''$  E to assess nitrogen management in Sunflower (*Helianthus annuus* L.) with conventional and nano urea under rainfed farming situations in the North Bank Plain Zone of Assam. The experiment confined to 10 treatments in Randomized Block Design (RBD) viz. T<sub>1</sub>: Control (No Nitrogen), T<sub>2</sub>: Soil application of 50% N, T<sub>3</sub>: Soil application of 100% N (RD), T<sub>4</sub>: 3 foliar application of 0.6% nano urea, T<sub>5</sub>: Soil application of 50% N + 2 foliar application of 1% conventional urea, T<sub>6</sub>: Soil application of 50% N + 2 foliar application of 2% conventional urea, T<sub>7</sub>: Soil application of 50% N + 2 foliar application of 3% conventional urea, T<sub>8</sub>: Soil application of 50% N + 2 foliar application of 0.2% nano urea, T<sub>9</sub>: Soil application of 50% N + 2 foliar application of 0.4% nano urea, T<sub>10</sub>: 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<sub>10</sub>. T<sub>9</sub> 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) and head diameter (16.70 cm). For most of the growth and phenological parameters, T<sub>9</sub> and T<sub>10</sub> were at par with each other. T<sub>1</sub> (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<sub>3</sub> but later T<sub>9</sub> and T<sub>10</sub> showed the maximum values. In terms of seed yield, test weight and chaffy grain %, T<sub>9</sub> showed the best results: (1505 kg/ha), (54 g/1000 seeds) and (20%) respectively, followed by T<sub>10</sub>. Whereas the highest stover yield was recorded in T<sub>10</sub>. The highest Benefit to Cost ratio (B:C=1.60) was obtained in the T<sub>9</sub>.

Keywords: Nitrogen management, Sunflower, Nano urea, Rainfed farming

**Comment [AR1]:**  $26^{\circ}43'30''$  N and  $93^{\circ}08'08''$  E" should be formatted consistently with degree symbols, like this: " $26^{\circ}43'30''$  N and  $93^{\circ}08'08''$  E."

**Comment [AR2]:** rainfed farming situations" should be corrected to "rainfed farming situations."

**Comment [AR3]:** viz." should be used instead of "viz," for better clarity: "viz., T<sub>1</sub>: Control..."

**Comment [AR4]:** 3 foliar application" should be corrected to "3 foliar applications."

**Comment [AR5]:** chlorophyll content index (30)" may need clarification; it's not clear what the value "30" represents.

**Comment [AR6]:** chaffy grain %" should be written as "chaffy grain percentage (%)."

**Comment [AR7]:** B:C=1.60" should be written as "B:C ratio of 1.60."

## 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. (Singh, *et al.*, 2009). 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 (Gebremedin, *et al.*, 2015). 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 (Singh, *et al.*, 2017). An optimum proportion of saturated and polyunsaturated fatty acids can be found in sunflower oil. When comparing several vegetable oils, Ryland (2003) discovered that sunflower oil was the healthiest because of its high oleic acid concentration. 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. (Kara, *et al.*, 2013). For the production of sunflowers, nitrogen is a vital and constant plant nutrient that is needed in higher concentrations than other plant nutrients (Schultz, *et al.*, 2018; Ullah, *et al.*, 2018). Nitrogen mainly promotes rapid development of roots and leaves, as well as the synthesis of chlorophyll, which in turn enhances biomass accumulation and yield characteristics. (Mahmood, *et al.*, 2001; Shehzad, *et al.*, 2015; Awais, *et al.*, 2015) To satisfy the varying nitrogen demands of crops, ordinary urea is often used as a nitrogen (N) fertilizer supplied during critical development phases. (Yang, *et al.*, 2011; Awais, *et al.*, 2011). However, because to 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. (Beig, *et al.*, 2020). 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

**Comment [AR8]:** The Introduction is skillfully crafted and efficiently communicates the information, but the citation adheres to a journal-style format.

sandy soils. 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. nano urea liquid particle is 20 to 50 nanometers in size, and it has thousand times extra surface area to volume than traditional granular urea. The availability of Nano Urea to crops has increased by more than 80% due to its small size (Tiwari, *et al.*, 2021).

## 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 coordinate 26°43'30" N and 93°08'08" E during the *rabi* season of 2021-22. The experiment consisted of 10 treatments which were laid out in Simple Randomized Block Design with 3 replications consisting of a total of 30 plots of (5X5) m<sup>2</sup> size each with a net area of 750 m<sup>2</sup> and gross area of 1062 m<sup>2</sup>. Treatment details are as follows, T<sub>1</sub>: Control (No Nitrogen), T<sub>2</sub>: Soil application of 50% N, T<sub>3</sub>: Soil application of 100% N (Recommended Dose), T<sub>4</sub>: 3 foliar application of 0.6% nano urea, T<sub>5</sub>: Soil application of 50% N + 2 foliar application of 1% conventional urea, T<sub>6</sub>: Soil application of 50% N + 2 foliar application of 2% conventional urea, T<sub>7</sub>: Soil application of 50% N + 2 foliar application of 3% conventional urea, T<sub>8</sub>: Soil application of 50% N + 2 foliar application of 0.2% nano urea, T<sub>9</sub>: Soil application of 50% N + 2 foliar application of 0.4% nano urea and T<sub>10</sub>: Soil application of 50% N + 2 foliar application of 0.6% nano urea. 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<sub>2</sub>O<sub>5</sub>:K<sub>2</sub>O kg ha<sup>-1</sup> 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<sup>-1</sup>) with medium available P<sub>2</sub>O<sub>5</sub> (33.74 kg ha<sup>-1</sup>) and K<sub>2</sub>O (187.80 kg ha<sup>-1</sup>).

### Preparation of the field

**Comment [AR9]:** In the sentence "The experiment consisted of 10 treatments which were laid out in Simple Randomized Block Design with 3 replications," you may want to add "a" before "Simple Randomized Block Design" to make it "a Simple Randomized Block Design."

**Comment [AR10]:** In the sentence "totaling 30 plots of (5X5) m<sup>2</sup> each, resulting in a net area of 750 m<sup>2</sup> and a gross area of 1062 m<sup>2</sup>," consider using "m<sup>2</sup>" consistently as "(5x5) m<sup>2</sup>" and "750 m<sup>2</sup>."

**Comment [AR11]:** In the sentence "Treatment details are as follows," you might consider changing it to "Treatment details are as follows."

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.

### **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.

### **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<sup>-1</sup> and after sowing the soil covering was done and pressed slightly to have good contact with the soil.

### **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.

### **Intercultural operation**

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

### **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.

### **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

**Comment [AR12]:** In the sentence "The stalk below the mature head was cut with a sharp knife or pruners and placed in the on," it seems there's an extra "on." It could be rephrased as "The stalk below the mature head was cut with a sharp knife or pruners and placed in the sun."

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. Threshing was done and yield attributes were recorded. After 7 days of harvesting, the plants were uprooted, weighed and recorded for stover yield estimation.

**Comment [AR13]:** In the sentence "The heads were sun-dried for 3-5 days," you might consider specifying whether they were sun-dried outdoors or in a controlled environment.

### Observations recorded

**Seed germination %:** Seed germination % was tested in the lab keeping the seeds on wet filter paper in Petri 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:

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

### Leaf Area Index (LAI):

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

**Plant dry matter accumulation (g plant<sup>-1</sup>):** 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 taken from the date of sowing to the first heading emergence in each plot was recorded as days taken till 50% of the plant population in each plot showed head emergence.

**Comment [AR14]:** The sentence "Days to 50 % heading: The total number of days taken from the date of sowing to the first heading emergence in each plot was recorded as days taken till 50% of the plant population in each plot showed head emergence." could be clarified by rephrasing as "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<sup>-2</sup>):** From each plot, the number of plants per m<sup>2</sup> was recorded and the average of the recorded data was taken for statistical analysis.

**Weight of seeds per head (g head<sup>-1</sup>):** 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 (g) 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 to kilogram per hectare.

**Harvest Index (%):**

$$\text{Harvest index (\%)} = \frac{\text{Economic yield } \left(\frac{\text{kg}}{\text{ha}}\right)}{\text{Total biological yield } \left(\frac{\text{kg}}{\text{ha}}\right)} \times 100$$

**Economic analysis:**

Cost of cultivation (Rs. ha<sup>-1</sup>), Gross return (Rs. ha<sup>-1</sup>), Net Return (Rs. ha<sup>-1</sup>) and Benefit-cost ratio were analyzed after harvesting of the crop .

**Comment [AR15]:** In the sentence "The mean value of the seed yield (g) per plant was calculated," you might consider specifying the units as "The mean value of the seed yield (grams) per plant was calculated."

**Comment [AR16]:** In the sentence "Per plot yields were then to kilogram per hectare," it appears there is a missing verb. It could be rephrased as "Per plot yields were then converted to kilograms per hectare."

## 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. However, the highest seedling emergence % was found when a 100% recommended dose of basal Nitrogen was applied (73.67%) and the lowest was recorded in the control treatment (60.73%).

### Plant height

The effect of nitrogen treatments on plant height 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. These results are also in conformity with the findings of Banerjee, *et al.*, (2014). The effect is represented in Table -1.

### 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 1. 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. (Marschner, 1995; Tisdale, *et al.*, 2003). Therefore, an increase in N application is consistent with an increase in crop growth.

### Relative leaf water content

**Comment [AR17]:** In the sentence "The effect is represented in Table -1," it might be clearer to say "The effect is presented in Table 1."

The data on relative leaf water content are presented in Table 2. 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 were concluded by Saud, *et al.*, (2017) that 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. Thus, these results may be taken into consideration while developing good feasible and cost-effective solutions for similar environmental conditions.

**Comment [AR18]:** In the sentence "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)," consider adding a space between "0.4%" and "nano urea" for consistency: "0.4 % nano urea."

### Leaf area index (LAI)

The data on the Leaf Area Index of sunflowers as influenced by treatments are presented in Table 2. 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. 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 (Krishna Murthy, *et al.*, 2011).

### Chlorophyll content index

The effect of treatments was found to be significant in terms of the Chlorophyll Content Index as shown in Table 2. The highest value (30.00) 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 (25.00). 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. Similar results were recorded by Havlin, *et al.*, (2005). The growth

**Comment [AR19]:** In the sentence "The highest value (30.00) was recorded under soil application of 50% N + 2 foliar applications of 0.4 % nano urea treatment," consider adding a space between "0.4%" and "nano urea" for consistency: "0.4 % nano urea treatment."

phase may have been prolonged and plant height may have risen as a result of high NPK doses as mentioned by (Sadiq,*et al.*, 2000). Likewise, Cechin and Fumis (2004) found that plants with superior N availability had substantially larger sunflower heights and shoot dry matters than plants with lower N availability. With the maximal dose, Yadav,*et al.*, (2009) also noted the maximum plant height and other growth characteristics.

### **Plant dry matter at 20 days interval**

The data on dry matter accumulation ( $\text{g plant}^{-1}$ ) of sunflower as influenced by different Nitrogen treatments are presented in Table 3. Statistically highest dry matter/ plant was found in treatment with soil application of 50% N + 2 foliar application of 0.4% nano urea as well as in 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.

**Comment [AR20]:** In the sentence "Statistically highest dry matter/ plant was found in treatment with soil application of 50% N + 2 foliar application of 0.4% nano urea as well as in soil application of 50% N + 2 foliar application of 0.6% nano urea (at par)," consider rephrasing for clarity: "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)."

### **Days to 50% heading**

The data on days to 50% heading of sunflower as influenced by different Nitrogen treatments are presented in Table 4. 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.

### **Days to maturity**

The data on the days to maturity of sunflowers, as influenced by different Nitrogen treatments, are presented in Table 4. 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).

### **Head diameter (cm)**

The data on the head diameter of sunflowers as influenced by different Nitrogen treatments are presented in Table 4. 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. The results obtained from this study are in line with the report by Oyinlola, *et al.*, (2010).

### Yield attributes

Effect of treatments on yield attributes and yield of sunflower are presented in Table 5. 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, as described by Awasthi, *et al.* (2011). 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. The results are harmonious with the report of Rasool, *et al.*, (2013). Similar findings were earlier reported by Syed, *et al.*, (2006) and Sarkar and Mallick (2009). 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

**Comment [AR21]:** In the sentence "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)," consider adding a space between "0.4%" and "nano urea" for consistency: "0.4 % nano urea (41.67 g)."

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 those of Monotti (1978), Crnobarac, *et al.*, (2004), and De Giorgio, *et al.*, (2007). 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. (Bonari *et al.*, 1992; Petcu and Petcu, 2006; Lauretti *et al.*, 2007; De Giorgio, 2007). The Harvest index was found to be significantly higher in treatments with control check nitrogen 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.

#### **Economics studies**

Economic analysis is presented in Table 6. 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.

#### **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 can be grown during *the rabi* season under the rainfed upland situation of Assam using a proper nitrogen management strategy. 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.

#### **REFERENCES**

**Comment [AR22]:** Please format the references and citations in the paragraph according to the guidelines of a journal format.

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**Table 1: 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
T1	9.00	20.00	35.33	60.33	68.00	12.67	22.20	27.33
T2	11.00	24.67	37.00	63.00	71.00	13.67	22.33	28.20
T3	12.20	25.00	40.00	66.00	74.67	14.85	23.67	29.80
T4	11.00	21.73	37.67	63.00	72.00	13.33	22.20	29.00
T5	10.87	24.44	39.33	66.00	74.00	14.43	23.20	30.70
T6	10.80	24.22	41.33	73.33	80.00	14.07	23.73	31.13
T7	11.27	24.32	43.67	69.00	76.00	13.67	23.63	30.13
T8	11.00	25.00	47.77	73.89	82.00	14.00	23.57	30.40
T9	10.97	25.33	49.33	75.33	84.00	13.53	23.93	32.67
T10	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 2:Effect of treatments on LAI, chlorophyll content index and RLWC% of sunflower**

Treatments	LAI		Chl content index	RLWC(%)
	60 DAS	90 DAS		
T1	2.80	3.40	64.00	25.00
T2	2.85	3.50	65.00	26.00
T3	3.04	3.90	67.00	28.00
T4	2.91	3.60	64.33	26.50
T5	3.00	3.80	66.00	27.50
T6	3.06	3.95	68.00	28.50
T7	2.95	3.70	65.00	27.00
T8	3.12	4.00	69.67	29.00
T9	3.20	4.20	71.00	30.00
T10	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 3: 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
T1	4.97	7.09	13.94	31.51	44.37
T2	5.50	8.07	15.17	34.65	49.67
T3	5.77	11.20	17.28	40.73	54.00
T4	5.00	9.50	14.30	33.03	46.33
T5	5.63	10.57	16.74	38.11	50.67
T6	5.53	10.67	19.17	42.43	57.67
T7	5.60	8.37	17.27	39.13	51.67
T8	5.63	10.43	18.67	42.43	57.67
T9	5.67	11.00	20.00	44.84	61.67
T10	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 4: Effect of treatments on Days to 50% heading, days to maturity and head diameter of sunflower**

<b>Treatments</b>	<b>Days to 50% heading</b>	<b>Days to maturity</b>	<b>Head diameter (cm)</b>
T1	65.00	97.00	11.00
T2	67.00	99.00	12.00
T3	70.00	102.00	14.07
T4	77.00	109.00	11.93
T5	69.00	101.00	13.37
T6	71.67	103.67	14.73
T7	74.00	106.00	12.83
T8	75.00	107.00	15.53
T9	76.00	108.00	16.70
T10	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

**Table 5: 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 <sub>1</sub>	21.10	25.03	38.00	1055.00	1925.00	35.40
T <sub>2</sub>	23.80	24.03	40.00	1190.00	2200.00	35.10
T <sub>3</sub>	26.00	21.03	41.67	1300.00	2625.00	33.11
T <sub>4</sub>	23.00	25.03	41.00	1150.00	2075.00	35.66
T <sub>5</sub>	25.00	22.03	38.33	1250.00	2400.00	34.24
T <sub>6</sub>	27.00	21.03	39.00	1350.00	2600.00	34.18
T <sub>7</sub>	24.53	23.03	41.00	1226.67	2500.00	32.92
T <sub>8</sub>	27.87	20.03	39.00	1393.33	2750.00	33.63
T <sub>9</sub>	30.10	18.90	41.67	1505.00	2900.00	34.16
T <sub>10</sub>	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

**Table6: Economics attributes sunflower as affected by treatments**

<b>Treatments</b>	<b>Cost of cultivation (Rs/ha)</b>	<b>Gross return Rs/ha</b>	<b>Net return Rs/ha</b>	<b>B: C ratio</b>
<b>T<sub>1</sub></b>	60930	73850	12920	1.21
<b>T<sub>2</sub></b>	61842	83300	21458	1.35
<b>T<sub>3</sub></b>	62754	91000	28246	1.45
<b>T<sub>4</sub></b>	69930	80500	10570	1.15
<b>T<sub>5</sub></b>	61962	87500	25538	1.41
<b>T<sub>6</sub></b>	62082	94500	32418	1.52
<b>T<sub>7</sub></b>	62382	85867	23485	1.38
<b>T<sub>8</sub></b>	63842	97533	33691	1.53
<b>T<sub>9</sub></b>	65842	105350	39508	1.60
<b>T<sub>10</sub></b>	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