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The influence of nano DAP and nano zinc foliar application on maize growth, with or without Bioneema application under Punjab region

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Abstract
A field experiment was conducted during the Kharif season of 2023, at Lovely Professional University Punjab, to study the response of maize (*Zea mays* L.) variety Pioneer P3378 to the integrated use of conventional fertilizers, nano fertilizers, and biopesticides. The experiment was laid out in randomized block design with eight treatments and three replications including control. Different levels of conventional fertilizers were applied with or without the combination of nano fertilizers and biopesticides. The combination of T_8 (50% RDF + Nano DAP + Nano Zn + Bioneema) produced the best-studied growth parameters. When the observations were recorded at 30 DAS treatment T_1 (100% RDF) which is the control plot recorded the highest values for all growth parameters except for the number of leaves but at 60 DAS and 90 DAS results revealed that T_8 (50% RDF + Nano DAP + Nano Zn + Bioneema) gave us the highest value for the studied growth parameters.

Keywords: Nano DAP, nano zinc, maize, Bioneema, growth parameters

Introduction
Maize is the third most important cereal crop with a wide adaptability and grown throughout the world for grain and fodder purposes which is also referred to as the "Queen of cereals." It is called the queen of cereals because it possesses the highest yield potential when compared to other cereal crops. Maize is a crop that has the highest productivity when compared to other cereal crops (Malhotra, 2017) [11]. Maize occupies 105.2 thousand hectares, producing 380.85 lakh tonnes in the Punjab State during the year 2022-23. The average yield was 39.30 quintals per hectare (15.90 quintals per acre). It is mostly cultivated as a Kharif crop, sown in the last week of May till the end of June and harvested in September-October. It has the yield potential of 10-12 tonnes/hectare and possibilities of further increase in productivity substantially up to 18 tonnes with better field management. The demand for maize is expected to double worldwide by 2050. In India, maize constitutes 30.16 million tonnes of production from an area of 9.87 million hectares, with an average productivity of 3057 kg/ha (FAOSTAT, 2020) [7]. Among the several causes, improper nutrient management is the one for low productivity of the crop. Hence, it has become our need to enhance the productivity of maize by adopting new scientific and sustainable nutrient management practices. A single nutrient source cannot alone meet the complete plant nutritional demand. Therefore, to overcome this problem a new class of fertilizers can be used that are called nano fertilizers that help in increasing the production of crops and promote sustainable agriculture. Increasing agricultural output, food security, and rural incomes all depend on soil fertility which means the ability of soil to produce crops, if soil fertility is not maintained then it will be tough for us to cultivate crops on that soil. To accomplish this, proper fertilizer application must be practiced in addition to being diversified in type. This method involves using specialized formulations, micronutrient fertilizers, and organic fertilizers. Farmers may improve soil structure, maximize nutrient availability, and encourage sustainable farming practices by implementing a multidimensional strategy, which will ultimately result in higher yields, better livelihoods, and stronger food systems. (Mahmood *et al.*, 2017) [10].
The overuse of synthetic fertilizers pollutes the air, water, and land and creates financial difficulties. The sustainable use of nano-fertilizers in crop productivity and soil fertility has demonstrated significant promise, with negligible or no environmental trade-offs.

Using nano fertilizers like nano urea instead of traditional nitrogenous fertilizers can be a beneficial option for supplying nitrogen to crops. Since nano-fertilizers have a size of 10^{-9} m, hence they have a high surface area to volume ratio, and are more mobile, which may improve agricultural output and plant nutrient uptake. These characteristics lead to the recognition of nano-fertilizers as a deliverable "smart system of nutrients." A new technology in agriculture, nano fertilizers have the potential to completely change crop productivity. Nanotechnology, with its ability to manipulate materials at the nanoscale, offers a novel approach to enhance nutrient availability and uptake by plants (Badawi, *et al.,* 2022) [3].

Increasing mineral nanoparticle fertilizer significantly increases the growth, yield, and yield components of maize (Damiyal *et al.,* 2017) [5].

Plant growth is enhanced, environmental impact is also decreased, and nutrient uptake efficiency is also increased with these nanoparticle-size nutrients. The uses, and advantages of nano fertilizers in the field of agriculture are examined in this research paper. When applied to crops at the appropriate time, nano fertilizers can boost yields while lowering environmental risks from runoff, evaporation, and leaching losses. India has a large problem with zinc shortage in its soil. The synthesis of growth factors like auxins, which are necessary for cell division and the formation of dry matter in plants, depends on zinc. The use of zinc oxide nanoparticles (ZnO NPs) is a well-thought-out biosecure substantial for biotic types since their effectiveness has been established to encourage the development of plants, in addition to the destruction of sickness and the defense of plants for their antimicrobial action.

Materials and Methods

The experiment was conducted during the kharif season of 2023 at the crop research farm of Lovely Professional University, Punjab. The soil of the experimental field was sandy loam. The experiment was laid out in a randomized block design with eight treatments and three replications. The variety Pioneer P-3378 was sown on 27 June 2023 with a spacing of 60 cm x 25 cm and a plot size of 5m x 3m was taken. The recommended dose of fertilizers for the crop is 120 - 60- 40 kg/ ha of N, P_2O_5, and K_2O. T_1 (100% RDF/Control), T_2 (75% RDF + Nano DAP), T_3 (75% RDF+ Nano Zn), T_4 (75% RDF + Bioneema), T_5 (50% RDF + Nano DAP+ Nano Zn), T_6 (50% RDF + Nano DAP + Bioneema), T_7 (50% RDF + Nano Zn + Bioneema), T_8 was (50% RDF + Nano DAP + Nano Zn + Bioneema) treatments were allocated to carry out the research. 15 kg/acre Bioneema was mixed with the soil at the time of field preparation. Nano DAP and Nano Zn were sprayed as a foliar application after 30 DAS. Zinc is an important nutrient for maize crop (Wieners *et al.,* 2019). The recommended dose of Nano DAP is 3-4ml of Nano DAP per liter of water and Nano Zn's recommended dose is 3-4gm per 15 liters of water. The second application of Nano DAP was done after 50 DAS. The observations were recorded at 30,60, and 90 DAS intervals of time. Three split doses of nitrogen were applied in the field, one at the time of sowing next after 30 DAS, and the last split after 50 DAS.

Results and Discussion

Growth attributes of maize

Plant height (cm)

Treatment T_1 (100% RDF) the control recorded the highest plant height at 30 DAS (79.39 cm). However, when the treatments Nano DAP and Nano Zn were applied at 30 DAS and 50 DAS. T_8 (50% RDF+ Nano DAP+ Nano Zn + Bioneema) recorded the highest plant height (178.06 cm) and (223.94 cm) at 60 DAS at 90 DAS respectively which was followed by T_2 (75% RDF+Nano DAP) (168.60 cm) and (220.74 cm) at 60 and 90 DAS respectively. At 60 and 90 DAS T_1 (100% RDF/Control) recorded the lowest values for plant height (139.79 cm) and (149.50 cm) respectively. Similar observations on plant height were reported by Reddy *et al.* (2022) [15]. It is observed that T_1 (100% RDF) gave the best results at 30 DAS which was treated with 100% RDF when compared to other treatments. However, once the treatments Nano DAP and Nano Zn were applied, variations in plant height at 60 and 90 DAS were observed. Similar findings were reported by Alzreejawi *et al.* (2020) [2] in which they concluded that when the combined application of conventional and nano fertilizers was applied increase in plant height was observed.

The use of Nano DAP and Nano Zinc contributed to the increased plant height because nanoparticles have a higher surface area to volume ratio, which can enhance their reactivity and uptake by plants (Al-Juthery *et al.* 2017) [19]. Nano DAP might have provided readily available phosphorus and Bioneema, a biopesticide has prevented the crop from pest attack which helped in increasing plant height.

Table 1 and Figure 1 show the recorded observations at 30, 60, and 90 DAS.

Fresh weight (gm)

Treatment T_1 (100% RDF) the control recorded the highest fresh weight (129.4gm) at 30 DAS. However, when the treatments Nano DAP and Nano Zn were applied after 30 DAS and 50 DAS it concluded that T_8 (50% RDF+ Nano DAP+Nano Zn + Bioneema) recorded the highest fresh weight (351.05gm) and (410.14gm) at 60 and 90 DAS respectively, followed by T_2 (75% RDF+NanoDAP) (400.81gm). At 60 DAS and 90 DAS T_1 (100% RDF/Control) fresh weight was observed (220.82gm) and (242.12gm) respectively which is the lowest when compared to other treatments. Al-Kraiti *et al.,* (2023) [1] concluded in their research that nano-fertilizers have a major impact on the vegetative growth of Maize plant.

Table 1: Plant height of maize at 30, 60, and 90 DAS as influenced by various treatments

Treatment	30 DAS	60 DAS	90 DAS
T_1	79.39	139.79	149.50
T_2	73.68	168.60	220.74
T_3	76.32	160.59	170.39
T_4	72.42	152.92	188.75
T_5	59.49	172.53	200.44
T_6	61.58	168.46	216.33
T_7	66.70	157.23	165.92
T_8	67.55	178.06	223.94
CD	3.5	3	6.1
F.Test	S	S	S
SE m±	1.2	1	2

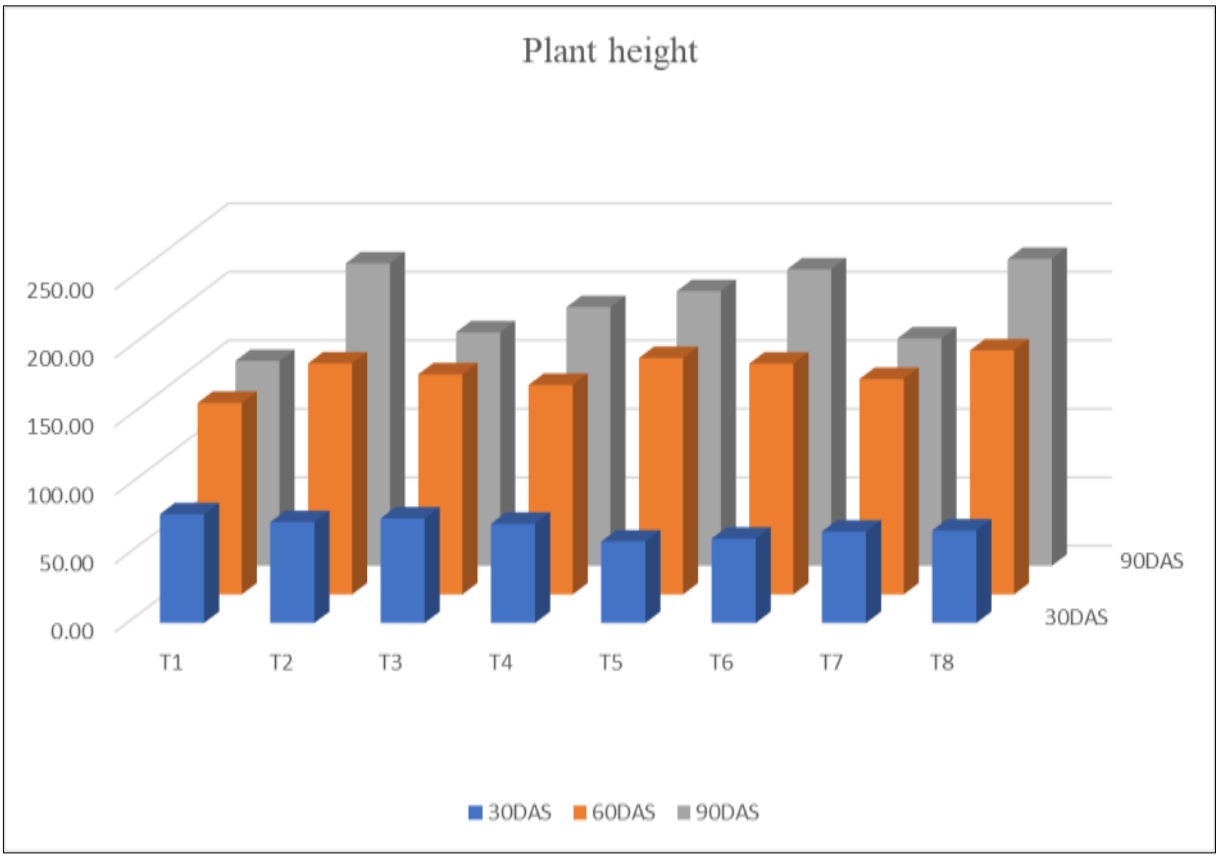

Fig 1: Plant height of maize at 30, 60, and 90 DAS as influenced by various treatments

Nano-fertilizers are known for their enhanced efficiency compared to conventional fertilizers (De Rosa *et al.*, 2010) [6], nano DAP and nano Zn may have facilitated better nutrient absorption by the plant roots, promoting overall growth and resulting in higher fresh weight. Bioneema have positively influenced plant-microbe interactions, leading to better nutrient assimilation, and ultimately contributing to increased fresh weight.

Table 2 and Figure 2 show the observations recorded at 30,60, and 90 DAS.

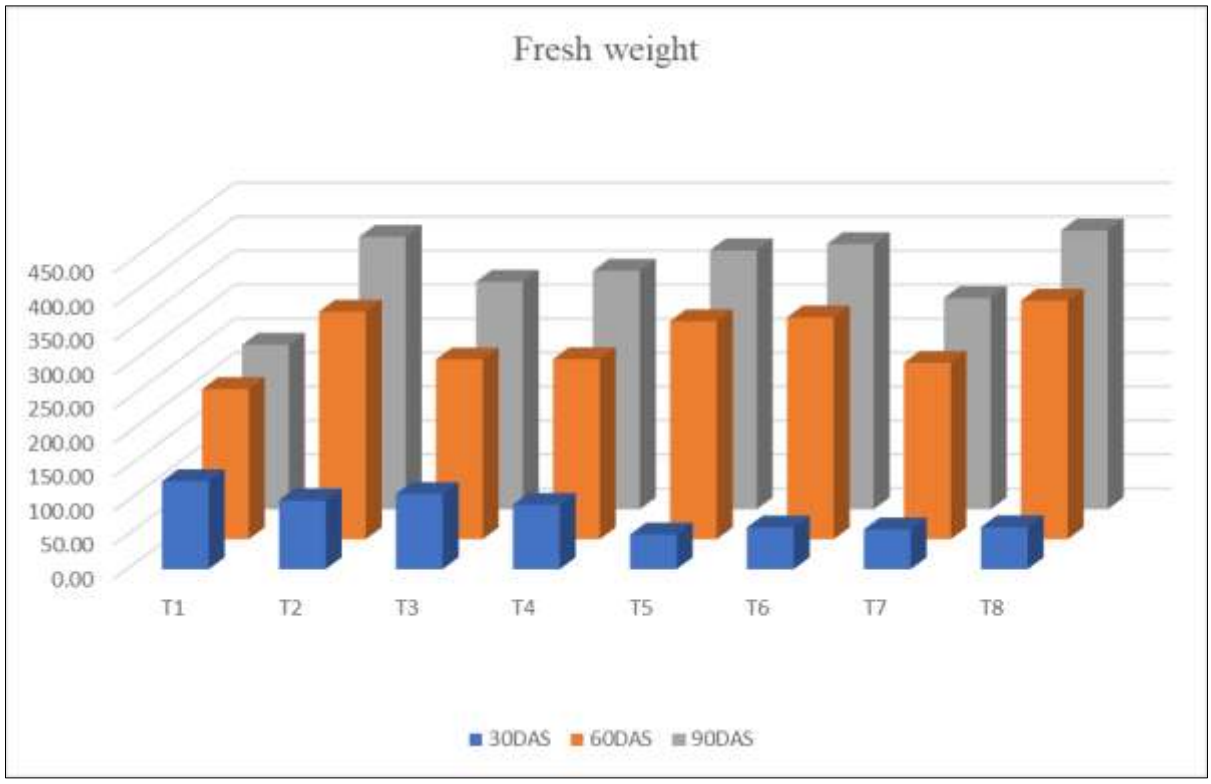

Fig 2: Fresh weight (gm) of maize at 30, 60, and 90 DAS as influenced by various treatments

Table 2: Fresh weight (gm) of maize at 30, 60, and 90 DAS as influenced by various treatments

Treatment	30 DAS	60 DAS	90 DAS
T_1	129.41	220.82	242.12
T_2	101.14	344.65	400.81
T_3	110.51	264.41	334.89
T_4	94.63	264.82	350.84
T_5	50.89	320.72	381.08
T_6	61.35	326.22	390.22
T_7	58.42	259.62	310.91
T_8	61.74	351.05	410.14
CD	2.9	6.3	8.4
F. Test	S	S	S
SE m±	0.9	2.1	2.8

Number of leaves

At 30 DAS, the treatment T_3 (75% RDF+Nano Zn) produced the highest number of leaves (7.57), but there was a sudden increase in number of leaves in T_8 (50% RDF+ Nano DAP+ Nano Zn + Bioneema) when treatments Nano DAP and Nano Zn were applied at 30 DAS and 50 DAS. T_8 (50% RDF+ Nano DAP+ Nano Zn + Bioneema) produced the highest number of leaves (13.49) and (14.02) at 60 and 90 DAS respectively followed by T_5 (50% RDF + Nano DAP+ Nano Zn) produced (12.51) and (13.69) at 60 and 90 DAS respectively.

Conventional fertilizers suffer from inefficiencies due to faster nutrient leaching, leading to nutrient loss from the soil before plants can fully utilize them. The controlled-release system of nano fertilizers ensures a steady supply of essential elements to plants, promoting growth and development. Nano fertilizers show increased efficiency in nitrogen, phosphorus, and potassium. This enhanced nutrient availability positively influenced leaf growth. Bioneema helps plants to remain healthier, due to reduced pest damage hence they can produce more leaves. Table 3 and Figure 3 show the observation recorded at 30, 60, and 90 DAS.

Table 3: Number of leaves in maize at 30, 60, and 90 DAS as influenced by various treatments

Treatment	30 DAS	60 DAS	90 DAS
T_1	6.78	7.39	8.62
T_2	5.48	10.58	13.31
T_3	7.57	11.77	12.02
T_4	5.21	12.42	13.30
T_5	5.88	12.51	13.69
T_6	5.12	11.71	12.36
T_7	4.73	11.48	12.23
T_8	5.88	13.49	14.02
CD	6.78	7.39	8.62
F.Test	5.48	10.58	13.31

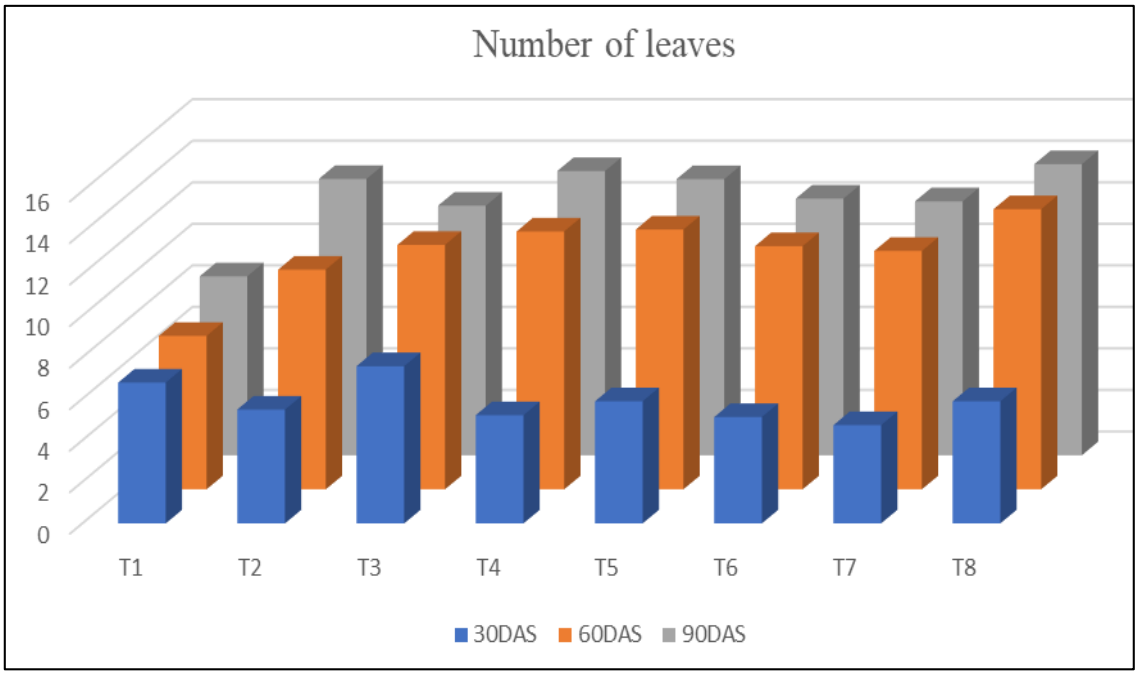

Fig 3: Number of leaves in maize at 30, 60, and 90 DAS as influenced by various treatments

Stem girth (cm)

Treatment T_1 (100% RDF), the control recorded the highest stem girth at 30 DAS (4.30 cm). It was also found that at 30 DAS the effect of treatments was non-significant. However, when the treatments Nano DAP and Nano Zn were applied after 30 DAS and 50 DAS, T_8 (50% RDF+ Nano DAP+ Nano Zn + Bioneema) showed the highest stem girth of (7.73 cm) and (8.08 cm) at 60 and 90 DAS respectively, followed by T_2 (75% RDF+Nano DAP) which recorded stem girth of (7.29 cm) and (7.67 cm) at 60 and 90 DAS respectively. At 60 DAS and 90 DAS T_1 (100% RDF /control) recorded the lowest values (6.24 cm) and (6.39 cm) respectively. Subbaiah *et al.*, (2016) [17] concluded in their research that stem diameter is enhanced due to the application of complete nano fertilizers like (Zn) when compared to the control.

Enhanced phosphorus availability from nano DAP likely stimulated cell division, it also influences vascular tissue development which contributes to higher stem girth (Hasan *et al.* 2016) [8]. Application of nano Zn likely improved zinc availability, which plays an important role in the elongation of cells. Bioneema contributed in controlling pests and diseases, and ensured that the plants remained healthy and stress-free. Table 4 and Figure 4 show the observation recorded at 30,60, and 90 DAS.

Table 4: Stem girth of maize at 30, 60, and 90 DAS as influenced by various treatments

Treatment	30 DAS	60 DAS	90 DAS
T_1	4.30	6.24	6.39
T_2	4.23	7.29	7.67
T_3	4.23	6.48	7.19
T_4	4.20	6.66	6.85
T_5	3.93	6.79	7.36
T_6	4.10	6.89	7.01
T_7	4.03	6.48	6.91
T_8	4.06	7.73	8.08
CD	0.3	0.6	0.6
F.Test	NS	S	S
SE m±	0.1	0.2	0.2

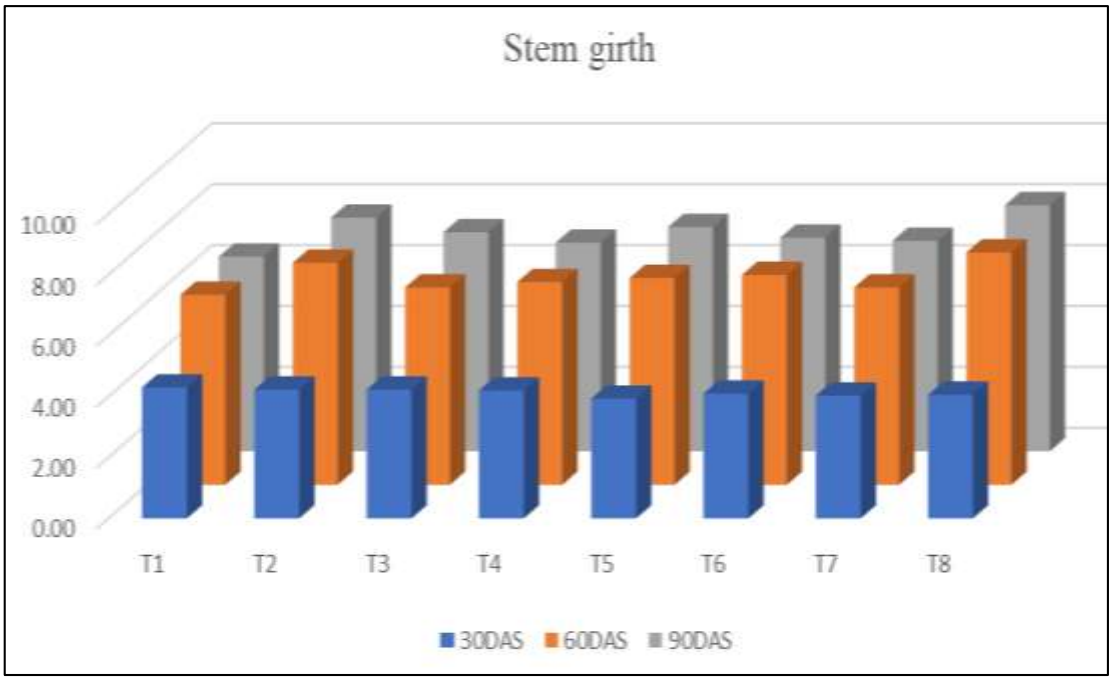

Fig 4: Stem girth of maize at 30, 60, and 90 DAS as influenced by various treatments

Leaf area (cm²)

Treatment T_1 (100% RDF), the control recorded the highest leaf area at 30 DAS (249.99 cm²). However, when the treatments Nano DAP and Nano Zn were applied after 30 DAS and 50 DAS, T_8 (50% RDF+ Nano DAP+ Nano Zn + Bioneema) recorded the highest leaf area of (671.58 cm²) and (690.14 cm²) at 60 and 90 DAS respectively. T_6 (50% RDF + Nano DAP+ Bioneema) was found to be at power with T_8 (50% RDF+ Nano DAP+ Nano Zn + Bioneema) that recorded leaf area of (656.85 cm²) and (675.38 cm²) at 60 and 90 DAS respectively. T_1 (100% RDF/Control) recorded the lowest values of (290.12 cm²) and (310.67 cm²) at 60 and 90 DAS respectively.

This finding is consistent with the research conducted by Buzeaa *et al.*, (2007) [4] which demonstrated that nano fertilizers can induce cell division and elongation in vegetative cells. This effect is achieved by their direct influence on leaf morphology, increasing the number of cell divisions which increase the leaf area of the plant and the same can be seen here as well.

Table 5 and Figure 5 show the recorded observations at 30,60, and 90 DAS.

Table 5 Leaf area of maize at 30, 60, and 90 DAS as influenced by various treatments.

Treatment	30 DAS	60 DAS	90 DAS
T1	249.99	290.12	310.76
T2	247.22	650.71	670.39
T3	236.48	482.56	501.81
T4	240.62	552.27	573.49
T5	171.21	611.38	630.72
T6	189.31	656.85	675.38
T7	200.88	560.82	579.64
T8	192.22	671.58	690.14
CD	15.80	23.6	24
F.Test	S	S	S
SE m±	5.2	7.8	7.9

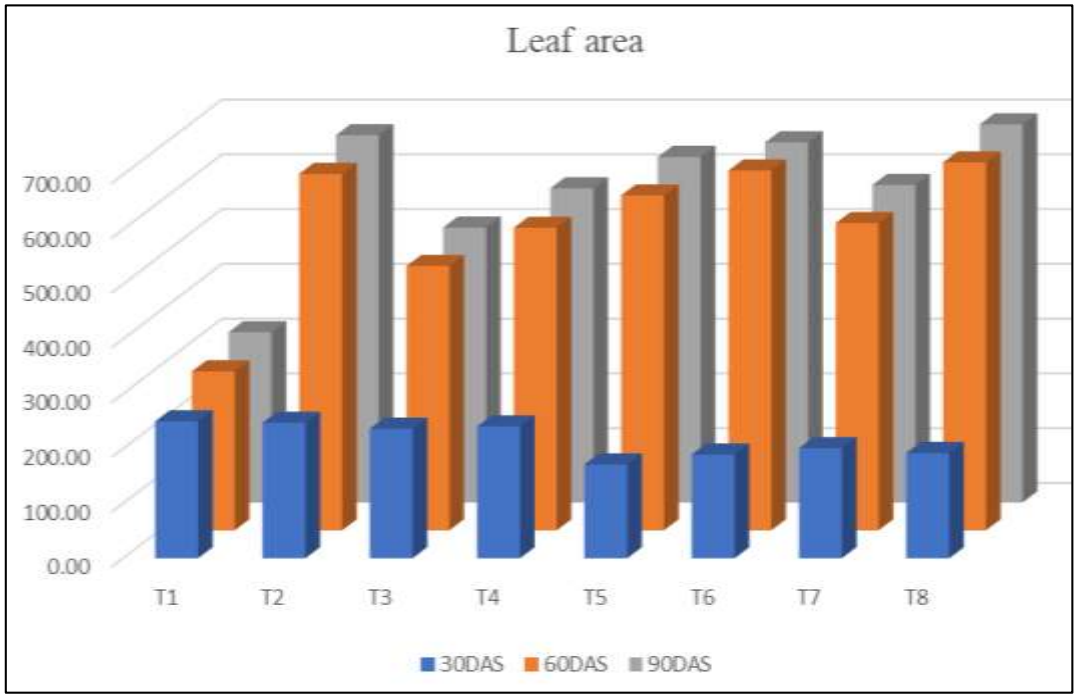

Fig 5: Leaf area of maize at 30, 60, and 90 DAS as influenced by various treatments

The various treatments significantly affected plant height, fresh weight, stem girth, leaf area, and number of leaves at 30, 60, and 90 DAS.

Conclusion

The combination of T_8 (50% RDF + Nano DAP + Nano Zn + Bioneema) was promised as the most effective treatment, resulting in significant improvements in various growth parameters compared to other treatments. While the control (T_1: 100% RDF) initially showed promising results at 30 DAS, T_8 consistently outperformed other treatments at 60 DAS and 90 DAS, indicating its superiority in enhancing maize growth. Overall, the finding from research suggests that the integrated use of conventional fertilizers, nano fertilizers, and biopesticides, holds potential for optimizing maize growth.

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