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Response of Sunflower to Nano Urea and Nano DAP under the *Alfisols* of Southern Karnataka during *Rabi* Season

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Abstract

A field experiment was conducted at AICRP on sunflower, Zonal Agricultural Research Station, UAS, GKVK, Bengaluru during *rabi*, 2022 and 2023 to study the effect of nano urea and nano DAP on growth and productivity of sunflower. The experiment was laid out in Randomized Complete Block Design with thirteen treatments (50% RDN + Nano N @ 4 ml, 50% RDN + Nano N @ 6 ml, 75% RDN + Nano N @ 4 ml, 75% RDN + Nano N @ 6 ml, 50% RDNP + Nano N & P @ 4 ml, 50% RDNP + Nano N & P @ 6 ml, 75% RDNP + Nano N & P @ 4 ml, 75% RDNP + Nano N & P @ 6 ml, RDF + Normal urea spray @ 1%, RDF + DAP spray @ 1%, RDF + FYM, RDF and absolute control) each replicated thrice. The results revealed that significantly higher plant height (187.15 cm), number of leaves per plant (26.82), leaf area (5203 cm^2 $plant^{-1}$), leaf area index (2.89), total dry matter production (123.80 g $plant^{-1}$), capitulum diameter (18.3 cm), no. of seeds per capitulum (1056), 100 seed weight (5.84 g), seed yield (61.77 g $plant^{-1}$), seed yield (1829 kg ha^{-1}) and stalk yield (4001 kg ha^{-1}) were recorded with the application of RDF + FYM and it was found at par with application of 75% RDN + Nano N @ 6 ml.

Keywords : Sunflower, *Rabi*, RDF, Nano urea, Nano DAP, Yield

Sunflower is one of the seven edible oilseeds under cultivation. Sunflower (*Helianthus annuus* L.) was domesticated as a food crop in North America, as early as 3000 BC, which was successfully developed as an oilseed in Russia in the early 1800s. Sunflower is a major source of vegetable oil in the world. Its seed contains around 48-53 per cent edible oil and 16 per cent proteins making it both an oil and protein species. Globally, sunflower is cultivated on an area of 28.72 m ha and it ranks third in oilseeds produced (57.27 mt) with a productivity of 1990 kg ha^{-1} representing 9 per cent of the total oilseeds production, preceded by soybean (60%) and rapeseed (12%) (USDA, 2023). It ranks fourth in vegetable oils market with 9.20 per cent (19 mt $year^{-1}$), after palm oil (36.50%), soybean oil (27.40%) and rapeseed oil (12.50%) (Pilorge, 2020). India accounts for about 15-20 per cent of global oilseeds area, 6-7 per cent of vegetable oil production and 9-10 per cent of the total edible oil consumption (Kumar and Tiwari, 2020). In India sunflower is grown in an area of 2.26 lakh ha with a production of 2.50 lakh tonnes and showcasing a productivity of 1011 kg ha^{-1} (Anonymous, 2023). Karnataka, Haryana and Odisha are the major states of which Karnataka accounts for about 53.13 per cent of the total area under sunflower cultivation and 47.18 per cent of sunflower production in India (Anonymous, 2021). In Karnataka it is grown in an area of 0.13 m ha with production of 0.10 mt and productivity of 802 kg ha^{-1} which is lower than national (931 kg ha^{-1}) and much lower than world's (2048 kg ha^{-1}) average productivity (Anonymous, 2020).

Sunflower is a day neutral and short-season crop, that allows the crop to be grown over a wide range of latitudes and year-round (*kharif, rabi* and summer) compared to other oilseed crops. Besides it has got wider adaptability to different soils, agro-climatic conditions and varied soil moisture levels. However, the reasons for the low productivity of sunflower in India are due to unavailability of adequate soil moisture and nutrients especially during winter and summer, erratic rainfall, imbalanced nutrient management, untimely weed management, low solar radiation and bud necrosis during the rainy season. Nutrient management plays an important role in enhancing crop yield, but the conventional application of fertilizers to increase productivity and profitability has brought about higher consumption of the nutrients, which ultimately leads to low nutrient use efficiencies, lower profits and increased environmental issues (Pampolino *et al*., 2012).

Conventional fertilizers offer nutrients in chemical forms that are not often fully accessible to plants. Additionally, the inversion of these chemical fertilizers to sparingly soluble forms in soil is the reason for the less utilization of most of the added macronutrients (Kumar *et al*., 2020). These problems make it imperative to go in for the repeated use of fertilizers. It is fairly well known that the yields of many crops have begun to drop as a result of imbalanced fertilization and a decrease in soil organic matter. In addition to the irreparable damage that the excess use of chemical fertilizers causes to the soil structure and mineral cycles, excessive (often indiscriminate) and imbalanced application of fertilizers spoils the soil microflora, plants and consequently, the food chains across ecosystems.

To deal with such situation, it is very important to develop smart materials that can systematically release nutrients to specific targeted sites in plants which could be beneficial in controlling their deficiencies in agriculture, while keeping intact the natural soil structure. Nano fertilizers possess unique features that enhance plant's performance in terms of ultrahigh absorption, increase in production, rise in rate of photosynthesis and significant expansion in the leave's surface area. Besides, the controlled release of nutrients contributes in preventing eutrophication and pollution of water resources. Replacement of traditional fertilizer by nanofertilizer is beneficial as upon application, it releases nutrients into the soil steadily and in a controlled way, thus preventing the water pollution (Naderi and Danesh-Shahraki, 2013). Nanopores and stomatal openings in plant leaves facilitate nanomaterial uptake and their penetration deep inside leaves leading to higher nutrient use efficiency (NUE) (Iqbal, 2019).

Nano urea (Liquid) which contains 4 per cent (40000 ppm) nitrogen by weight in its nano form, is a source of nitrogen which is a major essential nutrient required for proper growth and development of a plant. The availability of Nano Urea to crops increases by more than 80 per cent due to its small size (Tiwari *et al*., 2021). Nano DAP (liquid) is source of nitrogen and phosphorus. It contains about 8 per cent (80000 ppm) of nitrogen and 16 per cent (160000 ppm) of phosphorus. Nano fertilizers are appropriate alternatives to conventional fertilizers for gradual and controlled supply of nutrients in the soil (Teerthana *et al.*, 2022). Therefore, the present study is formulated with the objective of evaluating the effect of nano fertilizers on growth and productivity of sunflower.

Material and Methods

The field experiment was conducted during *rabi* 2022 and 2023 at AICRP on Sunflower, University of Agricultural Sciences, GKVK, Bengaluru, Karnataka, in E7 block, ZARS, situated at 13^{0}05' N latitude, 77^{0}34' E longitude and at an altitude of 924 m above mean sea level. The research station comes under the

Eastern Dry Zone (Zone-V) of Karnataka. The actual rainfall received throughout the cropping period at the experimental site was 203.6 mm and 1.0 mm during 2022 and 2023, respectively. The soil was red sandy loam in texture that comes under *Alfisol* soil order. Soil was acidic in reaction (pH 6.1), low in organic carbon content (4.5 mg kg^{-1}) with an electrical conductivity of 0.23 dS m^{-1}. The soil was initially medium in fertility status with respect to available nitrogen (275.7 kg ha^{-1}), high in phosphorous (38.73 kg ha^{-1}) and medium in potassium (258.42 kg ha^{-1}). Sunflower seeds were sown @ 5 kg ha^{-1}, using KBSH 85 hybrid at a spacing of 60×30 cm. The experiment was laid out in Randomized Complete Block Design with thirteen treatments and three replications. The thirteen treatments were, T_1: 50% RDN + Nano N @ 4 ml lit^{-1} water, T_2: 50% RDN + Nano N @ 6 ml lit^{-1} water , T_3:75 % RDN + Nano N @ 4 ml lit^{-1} water, T_4: 75% RDN + Nano N @ 6 ml lit^{-1} water, T_5: 50% RDNP + Nano N & P @ 4 ml lit^{-1} water, T_6: 50% RDNP + Nano N & P @ 6 ml lit^{-1} water, T_7: 75% RDNP + Nano N & P @ 4 ml lit^{-1} water, T_8: 75% RDNP + Nano N & P @ 6 ml lit^{-1} water, T_9: RDF + Normal urea spray @ 1%, T_{10}: RDF + DAP spray @ 1%, T_{11}: RDF + FYM, T_{12}: RDF and T_{13}: Absolute control. FYM for the treatment T_{11} was applied at the rate of 8 t ha^{-1} and RDF 90-90-60 N-$P_2O_5K_2O$ kg ha^{-1} which was applied as per the treatments. Nano N was applied through nano urea and Nano N & P was applied through Nano DAP which contains nitrogen and phosphorus. Total quantity of water used for foliar spray of fertilizers was 650 lit ha^{-1}. Rest of the agronomic practices were followed as per the recommendation for all the treatments in common.

Five plants from each plot were randomly selected from the net plot and tagged. These plants were used for recording growth and yield attributes observations. The plant height was measured from the ground level to base of the top leaf. The number of green leaves per plant were recorded from the tagged plants. The plants from the gross plot were cut above the ground and leaves were fed to leaf area meter for estimating the photosynthetically active area (leaf area). The same plants were oven dried at 65-70^{0}C and the dry weight per plant was noted. The plants from the net plot were harvested and threshed separately and the seed and stalk yield were recorded and expressed on hectare basis. The average of all the replications is expressed as mean values of the respective treatments. The data recorded on various parameters were subjected to Fisher's method of analysis of variance and interpretation of the data was made as given by Gomez and Gomez (1984). The level of significance used in 'F' and 't' test was P = 0.05. Whenever F-test was significant for comparison amongst the treatments means the critical differences (CD) was worked out. Otherwise against CD values abbreviation 'NS' (Non-significant) is indicated.

RESULTS AND DISCUSSION

The data pertaining to impact of nano urea and nano DAP application on growth parameters of sunflower is presented in Table 1 & 2. The pooled data analysis revealed that application of RDF + FYM recorded significantly higher plant height (187.1 cm) and total dry matter production (123.80 g plant^{-1}) at harvest and it was found at par with application of 75% RDN + Nano N @ 6 ml lit^{-1} (180.9 cm and 111.7 g palnt^{-1}), respectively. Whereas, the lower plant height (108.2 cm) and total dry matter production (45.28 g plant^{-1}) was recorded in absolute control. Significantly higher number of green leaves (26.82), leaf area (5203 cm^2 plant^{-1}) and leaf area index (2.89) at 60 DAS were recorded with the application of RDF + FYM and found at par with 75% RDN + Nano N @ 6 ml lit^{-1} (16.97, 2009 cm^2 plant^{-1} and 1.12), respectively. Significantly lower number of green leaves (16.97), leaf area (2009 cm^2 plant^{-1}) and leaf area index (1.12) at 60 DAS were recorded in absolute control. The increase in growth parameters with increase in the fertilizer application might be due to the synergistic effect of nano fertilizers on the efficiency of chemical fertilizer for greater absorption of nutrients by plant cells, resulting in maximum growth of plant parts and metabolic activities such as photosynthesis (Midde *et al*., 2022 and Ajitkumar *et al*., 2021). Increased growth parameters might be due to increased number of nodes resulting from cell

TABLE 1

Effect of nano urea and nano DAP on plant height and total dry matter production of sunflower at harvest

Treatment	Plant height			Total dry matter production		
	2022	2023	Pooled	2022	2023	Pooled
T_1	176.2	174.3	175.2	90.5	89.8	90.1
T_2	176.5	176.2	176.3	97.8	93.7	95.7
T_3	179.6	180.2	179.9	111.7	102.1	106.9
T_4	180.4	181.5	180.9	116.6	106.9	111.7
T_5	173.9	169.4	171.6	83.3	82.5	82.9
T_6	174.1	172.6	173.3	87.0	86.2	86.6
T_7	177.9	179.1	178.5	102.7	94.2	98.4
T_8	178.1	179.6	178.8	106.8	98.9	102.8
T_9	184.2	183.0	183.6	124.3	112.7	118.5
T_{10}	186.7	183.5	185.0	127.0	115.8	121.4
T_{11}	188.6	185.6	187.1	130.0	117.5	123.8
T_{12}	181.1	181.8	181.4	120.8	110.4	115.6
T_{13}	104.2	112.2	108.2	46.9	43.7	45.2
S.Em.±	8.22	8.17	8.20	5.06	4.31	4.00
CD at 5%	24.00	23.86	23.93	14.77	12.59	11.66

Treatment details :

T_1 : 50% RDN + Nano N @ 4 ml lit^{-1} T_2 : 50% RDN + Nano N @ 6 ml lit^{-1} T_3 : 75% RDN + Nano N @ 4 ml lit^{-1}
T_4 : 75% RDN + Nano N @ 6 ml lit^{-1} T_5 : 50% RDNP + Nano N & P @ 4 ml lit^{-1} T_6 : 50% RDNP + Nano N & P @ 6 ml lit^{-1}
T_7 : 75% RDNP + Nano N & P @ 4 ml lit^{-1} T_8 : 75% RDNP + Nano N & P @ 6 ml lit^{-1} T_9 : RDF + Normal urea spray @ 1%
T_{10} : RDF + DAP spray @ 1% T_{11} : RDF + FYM T_{12} : RDF
T_{13} : Absolute control

growth and cell elongation, which in turn produce more number of leaves (Devi *et al.*, 2024).

Providing 75 per cent of the recommended dose of nitrogen along with the full recommended amounts of phosphorus and potassium, supports the initial establishment and growth of plants and is further enhanced by foliar applications of nano form of nitrogen. The presence of a sufficient number of nitrogen molecules and a large surface area facilitates increased nitrogen absorption, which is critical since nitrogen is an essential component of chlorophyll, the green pigment crucial for photosynthesis and plant growth. An adequate supply of nitrogen at the optimal concentration reduces competition among plants for nutrients, leading to the production of a greater number of leaves and ultimately resulting in a higher leaf area and leaf area index. To maintain higher leaf area there should be higher number of leaves which in turn depends on plant height (Parameshnaik *et al.*, 2024; Asha Kiran, 2022 and Mallikarjuna, 2021).

Further, increase in dry matter production per plant might be attributed to better growth parameters *viz*., increased photosynthetic rate and higher leaf area. Soil application of conventional fertilizers along with foliar spray of Nano-N helped in increased nitrogen uptake which would have promoted robust plant growth, as nitrogen is essential for chlorophyll,

TABLE 2

Effect of nano urea and nano DAP on no. of green leaves, leaf area and leaf area index of sunflower at 60 DAS

Treatment	No. of green leaves plant^{-1}			Leaf area (cm^2 plant)			Leaf area index		
	2022	2023	Pooled	2022	2023	Pooled	2022	2023	Pooled
T_1	25.27	23.67	24.47	4687	3734	4210	2.60	2.07	2.34
T_2	25.67	23.83	24.75	4714	3763	4238	2.62	2.09	2.35
T_3	26.13	24.00	25.07	4938	3906	4421	2.74	2.17	2.46
T_4	26.43	24.33	25.38	5171	4501	4835	2.87	2.50	2.69
T_5	24.87	21.00	22.93	4543	3091	3817	2.52	1.72	2.12
T_6	25.07	23.50	24.28	4591	3414	4002	2.55	1.90	2.22
T_7	25.33	23.83	24.58	4829	3866	4347	2.68	2.15	2.42
T_8	25.80	24.00	24.90	4831	3894	4362	2.68	2.16	2.42
T_9	26.53	24.67	25.60	5314	4556	4934	2.95	2.53	2.74
T_{10}	26.80	25.50	26.15	5314	4769	5041	2.95	2.65	2.80
T_{11}	27.47	26.17	26.82	5334	5073	5203	2.96	2.82	2.89
T_{12}	26.27	24.50	25.38	5294	4553	4923	2.94	2.53	2.74
T_{13}	19.93	14.00	16.97	2854	1164	2009.	1.59	0.65	1.12
S.Em.±	1.06	1.04	0.68	267.79	250.84	170.14	0.14	0.10	0.09
CDat 5%	3.10	3.03	1.99	781.61	732.16	496.61	0.40	0.29	0.26

Treatment details :

T_1 : 50% RDN + Nano N @ 4 ml lit^{-1} T_2 : 50% RDN + Nano N @ 6 ml lit^{-1} T_3 : 75% RDN + Nano N @ 4 ml lit^{-1}

T_1:50 % RDN + Nano N @ 4 ml lit^{-1} T_2:50 % RDN + Nano N @ 6 ml lit^{-1} T_3:75 % RDN + Nano N @ 4 ml lit^{-1}

T_4:75 % RDN + Nano N @ 6 ml lit^{-1} T_5:50 % RDNP + Nano N & P @ 4 ml lit^{-1} T_6:50 % RDNP + Nano N & P @ 6 ml lit^{-1}

T_7:75 % RDNP + Nano N & P @ 4 ml lit^{-1} T_8:75 % RDNP + Nano N & P @ 6 ml lit^{-1} T_9:RDF + Normal urea spray @ 1%

T_{10}:RDF + DAP spray @ 1% T_{11}:RDF + FYM T_{12}:RDF

T_{13}: Absolute control

amino acids and proteins, resulting in higher dry matter production of the plant. Similar results were found by Sneha *et al.* (2024); Rawate *et al.* (2022) and Rajesh (2021). Further, higher growth parameters were recorded during *rabi* season of 2022 as compared to *rabi* season of 2023, which might be due to prevalence of congenial conditions for the growth and development of the crop.

The data related to yield and yield parameters of sunflower is presented in the Table 3. Pooled data of two seasons revealed that significantly higher capitulum diameter (18.30 cm), no. of seeds per capitulum (1056), 100 seed weight (5.84 g), seed yield (61.77 g plant^{-1}), seed yield (1829 kg ha^{-1}) and stalk yield (4001 kg ha^{-1}) were recorded with the application of RDF + FYM and found at par with the application of 75% RDN + Nano N @ 6 ml lit^{-1} (17.03 cm, 932, 5.36 g, 54.72 g plant^{-1}, 1682 kg ha^{-1} and 3529 kg ha^{-1}), respectively. Whereas, significantly lower capitulum diameter (11.03 cm), no. of seeds per capitulum (522), 100 seed weight (3.48 g), seed yield (22.92 g plant^{-1}), seed yield (678 kg ha^{-1}) and stalk yield (2279 kg ha^{-1}) were recorded in absolute control. Harvest index was found non significant. However, numerically higher harvest index was recorded with the application of 50% RDNP + Nano N&P @ 4 ml lit^{-1} (0.35) and 50% RDNP + Nano N & P @

TABLE 3

Effect of nano urea and nano DAP on yield parameters of sunflower

Treatment	Capitulum diameter (cm)			No. of seeds per capitulum			100 seed weight (g)			Seed yield (g $plant^{-1}$)		
	2022	2023	Pooled	2022	2023	Pooled	2022	2023	Pooled	2022	2023	Pooled
T_1	16.72	15.62	16.17	886	816	851	5.02	5.04	5.03	48.98	45.68	47.33
T_2	16.72	15.87	16.30	901	832	867	5.17	5.10	5.13	51.28	47.10	49.19
T_3	17.03	16.24	16.64	943	886	915	5.32	5.30	5.31	54.88	51.64	53.26
T_4	17.22	16.83	17.03	962	901	932	5.35	5.38	5.36	56.20	53.23	54.72
T_5	16.52	14.97	15.75	870	786	828	4.62	4.45	4.54	44.72	39.73	42.22
T_6	16.68	15.38	16.03	862	804	833	4.90	5.01	4.95	46.90	44.94	45.92
T_7	16.73	16.00	16.37	918	845	882	5.20	5.23	5.21	52.38	48.83	50.60
T_8	16.94	16.15	16.55	931	863	897	5.25	5.29	5.27	53.50	50.30	51.90
T_9	18.13	17.83	17.98	993	951	972	5.48	5.59	5.54	59.17	57.61	58.39
T_{10}	18.34	17.90	18.12	1013	973	993	5.55	5.59	5.57	60.71	59.35	60.03
T_{11}	18.50	18.10	18.30	1056	1055	1056	6.07	5.61	5.84	63.20	60.34	61.77
T_{12}	17.40	17.21	17.31	985	922	954	5.45	5.46	5.46	58.25	54.98	56.61
T_{13}	12.72	9.34	11.03	529	514	522	3.75	3.21	3.48	24.59	21.25	22.92
S.Em.±	0.74	0.75	0.54	41.89	42.22	37.35	0.33	0.29	0.24	2.43	2.63	1.91
CD at 5%	2.15	2.19	1.58	122.28	123.87	109.03	0.97	0.85	0.70	7.09	7.69	5.56

6 ml lit^{-1} (0.35) and the lower values in absolute control (0.23).

Yield parameters like capitulum diameter and number of seeds per capitulum, 100 seed weight and seed yield per plant depends on the nutrients supplied to the crop. The increase in yield parameters can be attributed to increased root growth and development, improved crop's growth performance, particularly the enhanced dry matter production and efficient translocation of photosynthates from source to sink. This increased photosynthetic activity leads to a greater accumulation and translocation of photosynthates to the plant's economic parts, such as grains, resulting in higher yields, which can be attributed to both enhanced source and sink strength (Ajithkumar *et al.*, 2021 and Rajput *et al.*, 2022). During the vegetative phase, nitrogen plays a crucial role in driving photosynthesis, supporting structural development and facilitating nutrient utilization, thereby establishing a strong foundation for robust and healthy plant growth and in the reproductive phase, it acts as a cofactor for enzymes involved in nutrient uptake and carbohydrate metabolism, enabling the efficient transport of nutrients to developing grains and supporting grain filling and development. Nitrogen also influences floret development, increasing the potential number of seeds per capitulum, promotes larger and heavier grains through the accumulation of starch and storage compounds (Leghari *et al.*, 2016). Adequate fertilizer supply promotes healthy crop growth and development leading to improved crop performance and productivity.

Yield is a multifaceted trait influenced by intricate interplay of internal and external factors, including carbohydrate production and mobilization, water and nutrient uptake from the soil and various environmental factors that affect the crop during its growth cycle, making it a complex and dynamic process. In the present study, the seed yield increased to the tune of 39.8 per cent and 64.2 per cent increase in stalk yield was observed with the application of 75% RDN + Nano N @ 6 ml lit^{-1} over the absolute control. This experiment showed that using nano urea as a nitrogen source can reduce the sunflower crop's nitrogen requirement by 25 per cent, without compromising yields, as the nano urea treatment achieved yields comparable to the RDF + FYM application. Foliar application of nano urea offers several advantages over conventional urea, including enhanced plant uptake, minimized nitrogen losses and increased nutrient availability, ultimately leading to improved crop yield and productivity. The tiny particle size of nano fertilizers offers a significantly higher surface area, enabling increased metabolic activity and facilitating enhanced photosynthesis, leading to boosted photosynthate production and improved plant growth when applied through foliar spray. The nutrient use efficiency of foliar applied nano urea is significantly higher (>80%) compared to soil-applied conventional urea (<40%) in crop plants.

As a result, even with 25 per cent reduction in nutrient supply, similar yield levels were achieved with 75 per cent recommended dose of nitrogen (RDN) with nano urea applied in two foliar sprays. The results are in conformity with the findings of Mahantesh (2023) and Vyankatrao *et al.* (2024) who reported that application of 75 per cent RDN with 2 foliar sprays of nano urea recorded at par yields with 100 per cent RDN. Further, the lower yield recorded in *rabi* 2023 might be due to high temperatures (34^{0}C). For sunflower the optimum temperature for better growth and productivity is 25-28^0 C, beyond which it leads to pollen abortion, pollen sterility ultimately resulting in lower seed setting and reduced productivity.

Soil enzyme activities were recorded at 60 DAS of the crop which is considered as the right time to estimate the presence of microbial activities in the soil. Significantly higher dehydrogenase, urease, acid phosphatase and alkaline phosphatase activity in the soil was recorded with the application of RDF + FYM (138.17 µg TPF g^{-1} hr^{-1}, 43.83 µg NH_4-N g^{-1} hr^{-1}, 37.86 µg PNP g^{-1} hr^{-1} and 17.79 µg PNP g^{-1} hr^{-1}), respectively and among the nano fertilizer applied treatments higher activity was recorded with the application of 75% RDN + Nano N @ 6 ml (106.50

µg TPF g^{-1} hr^{-1}, 31.67 µg NH_4-N g^{-1} hr^{-1}, 33.62 µg PNP g^{-1} hr^{-1} and 14.31 µg PNP g^{-1} hr^{-1}), respectively. The lower dehydrogenase, urease, acid phosphatase and alkaline phosphatase activity in the soil was recorded in absolute control (13.95 µg TPF g^{-1} hr^{-1}, 9.69 µg NH_4-N g^{-1} hr^{-1}, 15.43 µg PNP g^{-1} hr^{-1} and 4.71 µg PNP g^{-1} hr^{-1}), respectively.

Dehydrogenase activity is a widely recognized indicator of soil microbiological activity, as it reflects the oxidative metabolic processes carried out by microorganisms in the soil. Higher dehydrogenase activity in the soil was recorded with application of RDF + FYM which might be due to the application of FYM that resulted in increased biomass production and extensive root exudates in the rhizosphere likely contributed to the proliferation of microbial populations in the soil.

The acid phosphatase activity was much higher than alkaline phosphatase activity in all the treatments, which might be due to the acidic nature of the experimental soils. Increased phosphatase activity could be due to hydrolysis of organically bound phosphate into free ions, which are then taken up by plants. The plants utilize organic P fractions from the soil by the phosphatase activity enriched in the soil-root interface (Yosefi *et al*., 2011). The present study suggests that the increased phosphatase activity in the treatments with RDF + FYM application increased the available P content in soil.

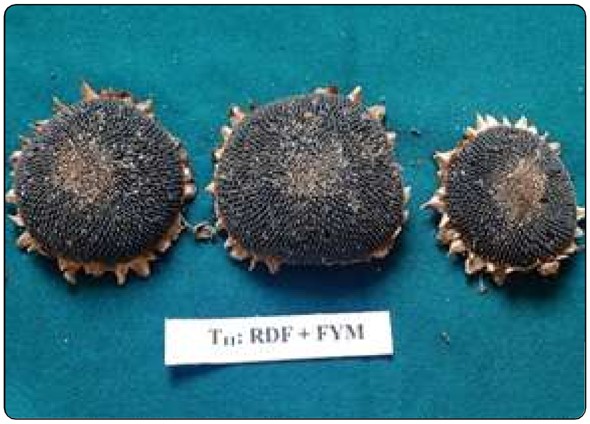
TABLE 4

Effect of nano urea and nano DAP on seed yield, stalk yield and harvest index of sunflower

Treatment	Seed yield (kg ha^{-1})			Stalk yield (kg ha^{-1})			Harvest index		
	2022	2023	Pooled	2022	2023	Pooled	2022	2023	Pooled
T_1	1596	1561	1579	2971	3317	3144	0.35	0.32	0.33
T_2	1624	1582	1603	3250	3356	3303	0.33	0.32	0.33
T_3	1692	1671	1682	3440	3461	3451	0.33	0.32	0.33
T_4	1711	1694	1703	3543	3516	3529	0.33	0.32	0.32
T_5	1545	1526	1536	2676	3080	2878	0.37	0.33	0.35
T_6	1571	1542	1557	2747	3185	2966	0.36	0.33	0.35
T_7	1653	1617	1635	3382	3379	3380	0.33	0.32	0.33
T_8	1675	1636	1656	3430	3452	3441	0.33	0.32	0.32
T_9	1782	1749	1766	3813	3554	3684	0.32	0.33	0.32
T_{10}	1808	1773	1791	3977	3900	3939	0.31	0.31	0.31
T_{11}	1846	1811	1829	4065	3937	4001	0.31	0.31	0.31
T_{12}	1737	1733	1735	3738	3537	3638	0.32	0.33	0.32
T_{13}	713	642	678	2253	2292	2272	0.24	0.22	0.23
S.Em.±	71.16	69.68	63.88	151.53	185.42	143.79	0.01	0.01	0.01
CD at 5%	207.69	203.37	186.45	442.27	541.20	419.68	NS	NS	NS

Treatment details :

T_1 : 50% RDN + Nano N @ 4 ml lit^{-1}
T_2 : 50% RDN + Nano N @ 6 ml lit^{-1}
T_3 : 75% RDN + Nano N @ 4 ml lit^{-1}
T_4 : 75% RDN + Nano N @ 6 ml lit^{-1}
T_5 : 50% RDNP + Nano N & P @ 4 ml lit^{-1}
T_6 : 50% RDNP + Nano N & P @ 6 ml lit^{-1}
T_7 : 75% RDNP + Nano N & P @ 4 ml lit^{-1}
T_8 : 75% RDNP + Nano N & P @ 6 ml lit^{-1}
T_9 : RDF + Normal urea spray @ 1
T_{10} : RDF + DAP spray @ 1%
T_{11} : RDF + FYM
T_{12} : RDF
T_{13} : Absolute control



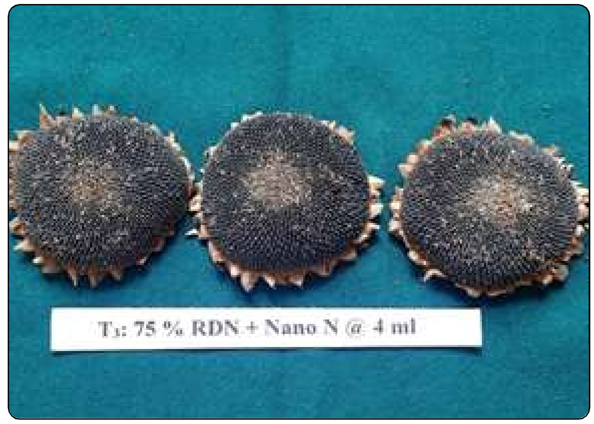


Plate 1 : Comparison of yields of sunflower in different treatments

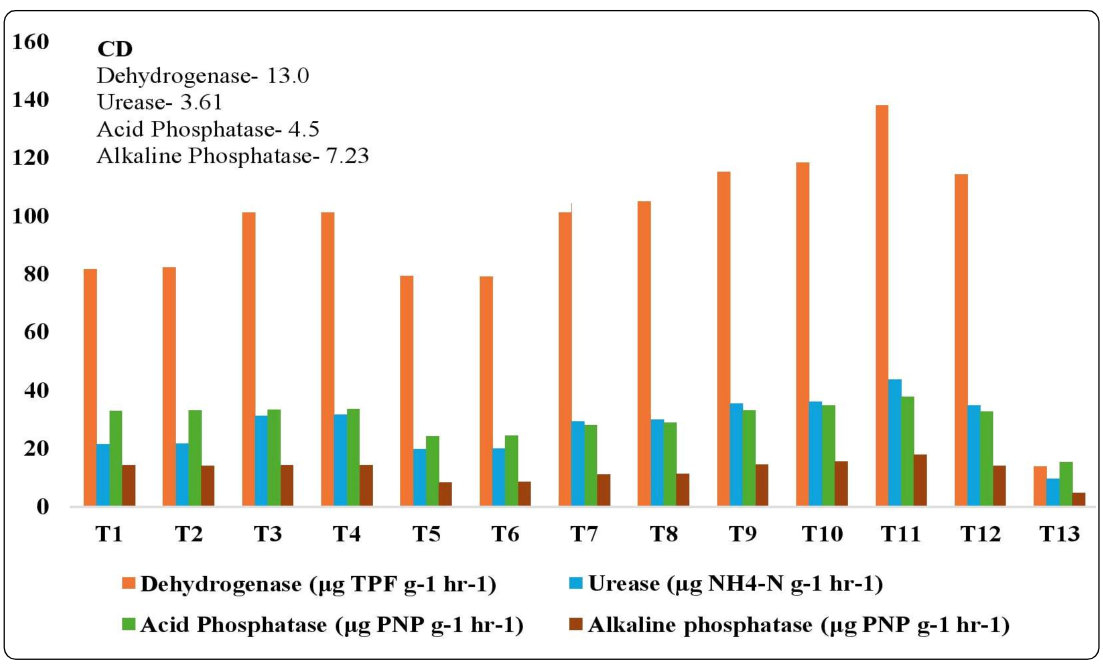


Fig. 1 : Effect of nano nitrogen and phosphorus on soil enzymes activity at 60 DAS of Sunflower during *rabi* 2023

Urease activity in the soil increased with increased rate of nitrogen application and was higher in RDF + FYM applied treatment. This might be due to the fact that urease enzyme plays an important role in the hydrolysis of urea applied to the soil. Enzyme activity increases in the presence of substrate urea. These results are in conformity with the findings of Maruthi (2019) and Rohitha *et al*. (2024).

Growth and yield of sunflower with the application of nano nitrogen and nano phosphorus was found to be on par with application of conventional fertilizers. Findings of the present study revealed that by the application of nano nitrogen, 25 per cent of the conventional urea requirement can be reduced without significant reduction in yield of the crop.

References

AJITKUMAR, K., YOGENDRA, K., SAVITHA A. S., AJAYAKUMAR, M. Y., NARAYANASWAMY, C., RAMESH, R., KRUPASHANKAR, M. R. AND BHAT, S. N., 2021, Effect of IFFCO nanofertilizer on growth, grain yield and managing turcicum leaf blight disease in maize. *Int. J. Plant Soil Sci*., **33** (16) : 19 - 28.

ANONYMOUS, 2020, Crops and livestock products. Food and Agriculture Organisation of the United Nations. https://www.fao.org/faostat/en/#data/QCL.

ANONYMOUS, 2021, Department of agriculture and farmer's welfare. Available on http://agricoop.gov.in/en/Oilseeds#gsc.tab=0.

ANONYMOUS, 2023, Department of agriculture and farmer's welfare. Available on http://agricoop.gov.in/en/Oilseeds#gsc.tab=0.

ASHA KIRAN, 2022, Studies on influence of nano nitrogen and phosphrous on growth and yield of maize (*Zea mays* L.). *M.Sc. (Agri.) Thesis*, Univ. Agric. Sci., Bengaluru, Karnataka, India.

DEVI, S., KALITA, J., BORKOTOKI, B., BARUAH, N. AND CHOUDHURY, H., 2024, 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. *Asian Res. J. Agric.*, **17** (1) : 22 - 32.

IQBAL, 2019, Nano-fertilizers for sustainable crop production under changing climate: A global perspective. *Sustain. crop prod*., pp. : 1 - 12. DOI: http://dx.doi.org/10.5772/intechopen.89089.

KUMAR, V. AND TIWARI, A., 2020, Sparking yellow revolution in India again. *Rural Pulse*, **34** : 1 - 4.

KUMAR, Y., TIWARI, K. N., NAYAK, R. K., ABHIMANYU, R., SINGH, S. P., SINGH, A. N., KUMAR, Y., TOMAR, H., SINGH, T. AND RALIYA, R., 2020, Nanofertilizers for increasing nutrient use efficiency, yield and economic returns in important winter season crops of Uttar Pradesh. *Indian J. Fert*., **16** (8) : 772 - 786.

LEGHARI, S. J., WAHACHO, N. A., LAGHARI, G. M., LAGHARI, A. H., BHABHAN, G. M., TALPUR, K. H., AHMED, T., WAHOCHO, S. A. AND LASHARI, A. A., 2016, Role of nitrogen for plant growth and development: A review. Adv. *Environ. Biol*., **10** (9) : 209 - 218.

MAHANTESH, B. N., 2023, Studies on mitigation of nitrogen losses and greenhouse gases emission in aerobic rice. *Ph.D. Thesis*, Univ. Agric. Sci., Bengaluru, Karnataka, India.

MALLIKARJUNA, P. R., 2021, Effect of nano nitrogen and nano zinc nutrition on nutrient uptake, growth and yield of irrigated maize during summer in the southern transition zone of Karnataka. *M.Sc. (Agri.) Thesis*, Univ. Agric. Sci., Shivmogga, Karnataka, India.

MARUTHI, G. M., 2019, Effect of humic acid based liquid nutrient formulations on soil biological properties and growth and yield of maize (*Zea mays* L.) and tomato (*Lycopersicon esculentum* Mill.). *M.Sc.(Agri.) Thesis*, Univ. Agric. Sci., Bengaluru, Karnataka, India.

MIDDE, S. K., SARAVANA, M., PERUMAL, G., MURUGAN, R., SUDHAGAR, VIKRAM SAI, MATTEPALLY AND BADA, M. R., 2022, Evaluation of nano urea on growth and yield attributes of rice (*Oryza sativa* L.). *Chem. Sci. Rev. Lett*., **11** (42) : 211 - 214.

NADERI, M. R. AND DANESH-SHAHRAKI, A., 2013, Nanofertilizers and their roles in sustainable agriculture. *Int. J. Agric. Crop Sci*., **5** (19) : 2229 - 2232.

PAMPOLINO, M. F., WITT, C., PASUQUIN, J. M., JOHNSTON, A. AND FISHER, M. J., 2012, Development approach and evaluation of the nutrient expert software for nutrient management in cereal crops. *Comput. Electron. Agric.*, **88** : 103 - 110.

PARAMESHNAIK, C., KALYANA MURTHY, K. N., HANUMANTHAPPA, D. C., SEENAPPA, C., REDDY, Y. A. N. AND PRAKASHA, H. C., 2024, Influence of nano fertilizers on growth and yield of maize. *Mysore J. Agric. Sci.*, **58** (1) : 211 - 221.

PILORGE, E., 2020, Sunflower in the global vegetable oil system : Situation, specificities and perspectives. *OCL*, **27** : 34.

RAJESH, H., 2021, Studies on foliar application of nano nitrogen (N) and nano zinc (Zn) in sweet corn (*Zea mays* L. saccharata). *M. Sc. (Agri.) Thesis*, Univ. Agril. Sci., Raichur, Karnataka, India.

RAJPUT, J. S., THAKUR, A. K., NAG, N. K., CHANDRAKAR, T. AND SINGH, D. P., 2022, Effect of nano fertilizer in relation to growth, yield and economics of little millet (*Panicum sumatrense* Roth) under rainfed conditions. *Pharm. Innov. J.*, **11** (7) : 153 - 156.

RAWATE, D., PATEL, J. R., AGRAWAL, A. P., AGRAWAL, H. P., PANDEY, D. AND PATEL, C. R., 2022, Effect of nano urea on productivity of wheat (*Triticum aestivum* L.) under irrigated condition. *J. Pharm. Innov.*, **11** (9) : 1279 - 1282.

ROHITHA, D. S., MAMATHA, B., CHANNAKESHAVA, S., SATHISH, A., LALITHA, B. S. AND REDDY, S. K. M., 2024, Evaluating the varied impacts of conventional versus nano fertilizers on soil nutrient levels, utilization efficiency and biological activity in acidic soil. *Asian J. Soil Sci. Plant Nutri.*, **10** (1) : 336 - 346.

SNEHA, M. A., MUDALAGIRIYAPPA, THIMMEGOWDA, M. N. AND HANUMANTHAPPA, D. C., 2024, Effect of nitrogen levels and method of fertilizer application on growth and productivity of finger millet. *Mysore J. Agric. Sci.*, **58** (1) : 326 - 339.

THEERTHANA, T., YOGANAND, S. B., THIMMEGOWDA, M. N., JAYADEVA, H. M., PRAKASH, S. S. AND MALLIKARJUN GOWDA, P., 2022, Nano nitrogen and nano zinc fertilizers: Impact on sustainable paddy production under different systems of establishment. *Mysore J. Agric. Sci.*, **56** (3) : 272 - 278.

TIWARI, K., KUMAR, Y., NAYAK, R., RAI, A., SINGH, J. AND SRIVASTAVA, S. S. A., 2021, Nano-Urea for enhancing yield and farmers profit with potato in Uttar Pradesh. Ann. *Plant Soil Res.*, **23** (4) : 495 - 500.

USDA (United States Department of Agriculture), 2023, World agriculture production: Sunflower seed area, yield and production. https://apps.fas.usda.gov/psdonline/circulars/production.pdf

VYANKATRAO, K. S., BABURAO, A. P., AMRUT, R. P., JAIPAL, K. P. AND ASHROBA, I. O., 2024, Effect of foliar application of nano urea on growth, nutrient uptake, yield and quality of sunflower. *Int. J. Plant Soil Sci.*, **36** (4) : 184 - 190.

YOSEFI, K., GALAVI, M., RAMRODI, M. AND MOUSAVI, S. R., 2011, Effect of bio-phosphate and chemical phosphorus fertilizer accompanied with micro nutrient foliar application on growth, yield and yield components of maize. *Australian J. Crop Sci.*, **5** : 175 - 180.