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Evaluation of Nano-DAP on Plant Growth, Enzymatic Activity and Yield in Paddy (*Oryza sativa* L.)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

A field experiment was conducted during *Rabi* 2022-23 at the College of Agriculture, Rajendranagar, Hyderabad, Telangana, focusing on the impact of using nano-DAP through foliar application on plant growth, yield, enzymatic activity and nutrient content in paddy variety KNM 1638. The experiment employed a randomized block design (RBD) with seven different treatments, each replicated three times. The study recorded various growth parameters, enzymatic activity, yield and nutrient content. The results demonstrated that, application of 100% NK + 75% P in combination with two foliar sprays of nano-DAP at both tillering and panicle initiation stages (T_6) led to superior plant growth parameters such as number of tillers hill^{-1} (13.18), total dry matter (42.12 g hill^{-1}), increased yield parameters such as number of productive tillers hill^{-1} (11.25), number of grains panicle^{-1} (297) and yield (7530.86 kg ha^{-1}) and nutrient content such as N (2.33%), P (0.19%) and K content (1.68%). The enzyme Glutamine Synthetase (GS) activity was found to be significantly higher with the application of 100% NPK with two foliar sprays of nano-DAP at tillering and panicle initiation stages (T_3). While the acid and alkaline phosphatase activity recorded maximum with 100%.

Keywords: Rice; foliar application; nano-DAP; enzyme activity; yield.

1. INTRODUCTION

Rice, a vital nutritional staple food crop for over 65% of the world's population [1]. belongs to the Poaceae (Gramineae) family. In India, rice has been affectionately referred to as 'Dhanya,' signifying its role as a sustainer of humanity. Globally, rice covers 165.25 million hectares, with a yield of 512.49 million tonnes. India ranks second in rice production, producing 136 million tons from 47.70 million hectares and with a productivity of 4.28 metric tonnes hectare^{-1} [2]. In Telangana, rice covers 97.98 lakh acres, resulting in a production of 202.18 lakh tonnes [3].

Major fertilizers consumed in Telangana state account to 37 lakh MT in 2021-22 [3]. Excessive use of chemical fertilizers causes eutrophication in the water bodies, decreases the soil quality, increases the acidity of the soil and ultimately harms the ecological environment [4]. To mitigate these adverse effects, it has been crucial to switch over to sustainable agricultural practices such as usage of nano fertilizers. These with their tiny particle size and higher surface area, enhance nutrient absorption, reduce environmental impact and boost crop yields by efficiently delivering nutrients to plants [5]. Nano-DAP, a white liquid fertilizer which facilitates the availability of phosphorous and nitrogen in the ratio of 2.5:1 to plants, promotes robust crop growth and higher yields. Nano-DAP exhibits higher absorption capacity, readily infiltrates into plant tissues through stomata when applied as a foliar spray after dilution (Coromandel.biz).

An innovative approach has been used to reduce the reliance on chemical fertilizers, enhance nutrient absorption in rice plants and ultimately elevate nutrient utilization and crop yields. Hence, a study was taken up to evaluate the efficiency of combining both conventional and nano fertilizers in rice.

2. MATERIALS AND METHODS

The study was conducted in the *Rabi* Season 2022-23 at the College of Agriculture, Rajendranagar, Hyderabad, Telangana. The experiment was laid out in Randomized Block Design (RBD) with seven treatments, each replicated thrice. The treatments comprised of T_1: (100% NPK), T_2: (100% NPK + one foliar spray of Nano DAP at 20-25 DAT), T_3: (100% NPK + two foliar sprays of Nano-DAP at 20-25 DAT and 45-50 DAT), T_4: (100% NK + 75% P), T_5: (100% NK + 75% P + one foliar spray of Nano DAP at 20-25 DAT), T_6: (100% NK + 75% P + two foliar sprays of Nano-DAP at 20-25 DAT and 45-50 DAT), T_7: (100% NK + 0% P). The recommended fertilizer application was 150:60:40 kg ha^{-1} of N, P_2O_5 and K_2O with a spacing of 30 cm x 10 cm. Nitrogen was applied as urea in three split doses at basal, 30 DAT and 60 DAT, whereas P and K were applied as a basal dose. Each plot size was 50 m × 20 m. Biometric data were gathered from five selected hills within each replication, identified across all treatments and the resultant average values were documented.

Nano-DAP developed by Coromandel International Limited (CIL) was used in the study.

Nano DAP contains N (2% w/v) and P_2O_5 (5% w/v) with a particle size less than 100 nm. The recommended dosage used was 500 ml acre^{-1}, applied at the tillering and panicle initiation (PI) stages of crop growth. This innovative nano-formulation promotes improved crop growth and yield, reduces environmental impact and enhances farmer profitability.

3. RESULTS AND DISCUSSION

3.1 Number of Tillers Hill^{-1}

In paddy plants, tillering is a critical stage of growth where new shoots or tillers emerge from the base of the main stem. 100% NK + 75% P + two foliar sprays of nano-DAP (T_6) resulted in development of 13.18 tillers hill^{-1} at the time of harvest as compared to 9.16 tillers hill^{-1} with 100% NK + 0% P (T_7). A significant increase (30.5%) in tiller count hill^{-1} has been observed by the application of nano-DAP during tillering and PI stages (Table 1). Rajput et al*.* [6] observed similar results, stating that a higher specific surface area and small particle size led to enhanced penetration and nutrient uptake as well as a higher number of tillers (3.47) over control (2.23).

3.2 Total Dry Matter (TDM) (g hill^{-1})

Phosphorous plays an important role in photosynthesis and production of carbohydrates resulting in an increase in dry matter which has been supplied by nano-DAP through foliar application. Minimum dry matter was recorded in 100% NK (T_7) with 32.76 g hill^{-1}. The application of 100% NPK + one (T_2) + two (T_3) foliar sprays and 100% NK + 75% P + one (T_5) + two (T_6) foliar sprays of nano-DAP at tillering and PI stages were found to be on par with and recorded an increase of 22.22% over T_7. This significantly showed that application of nano-DAP at tillering and PI stages, increased in total dry matter [7].

3.3 Glutamine Synthetase Activity (µ mol mg^{-1} min^{-1})

Glutamine synthetase (GS), a key enzyme responsible for converting amino acids into amides and facilitates the conversion of glutamate to glutamine. This process involves the utilization of NH_4^+, ATP and a divalent cation such as Mg^{2+} or Mn^{2+} as a cofactor. GS serves as a central regulatory factor in governing nitrogen assimilation in plants [8]. Foliar sprays of nano-DAP at tillering and PI stages showed a significant difference (Table 2 and Fig. 1). Application of nano-DAP along with 100% NPK (T_3) showed maximum GS activity in paddy, whereas under low fertilizer dose and with no P i.e., 100% NK + 0% P (T_7), resulted in lower activity of GS. This indicates that, foliar spray of nano-DAP influences the supply of ammonium to the plant, stimulating GS activity. These results align with the findings of Kaur et al. [9] where higher nitrogen content positively impacted GS activity.

3.4 Acid Phosphatase Activity (µ mol g^{-1} min^{-1})

Acid phosphatase (ACP) catalyzes the hydrolysis of phosphoric acid esters under acidic conditions. ACP plays a crucial role in the metabolism of phosphorus. ACP has been located in plant's cellular compartments such as vacuoles and acidic organelles. ACP catalyzes the mobilization of organic phosphorus compounds such as phosphate esters and nucleotides into inorganic phosphate that plants can absorb and utilize. ACP activity has been correlated negatively with phosphorous content in leaves [10]. Under low phosphorous content (100% NK + 0% P) (T_7), ACP showed maximum activity both before and after foliar sprays of nano-DAP. When 100% NPK with two foliar sprays of nano-DAP) (T_3) are administered in sufficient quantities, ACP did not produce considerable action (Table 3).

3.5 Alkaline Phosphatase Activity (µ mol g^{-1} min^{-1})

Plants use alkaline phosphatase (ALP) enzyme to catalyze the hydrolysis of phosphomonoesters in an alkaline environment, which plays a critical role in the metabolism of phosphorus. In alkaline conditions, this enzyme activity causes organic molecules to release inorganic phosphate (Pi) which performs photosynthesis, respiration and other cellular process like energy transfer, nucleic acid synthesis ultimately resulting in overall plant growth [11]. The ALP activity in paddy leaves was found to be minimum with the application of 100% NPK + two foliar sprays of nano-DAP (T_3), whereas maximum activity has been recorded with 100% NK + 0% P (T_7) where no P was supplied (Table 3). Similarly a three fold increase in ALP activity has been reported under P deficient conditions [12].

Table 1. Growth and yield parameters as influenced by nano-DAP

Treatments	No. of tillers hill^{-1}	Total Dry Matter (g hill^{-1})	Productive tillers hill^{-1}	Grains panicle^{-1}	Grain yield (kg ha^{-1})	Nitrogen (%)	Phosphorous (%)	Potassium (%)
T_1	11.07	37.18	9.60	275.00	7432.10	0.65	0.17	1.54
T_2	11.73	38.67	9.80	274.37	7432.10	1.17	0.18	1.54
T_3	12.29	40.77	10.92	292.00	7481.48	2.01	0.19	1.68
T_4	10.58	35.12	9.50	269.00	7358.02	0.09	0.15	1.46
T_5	12.21	39.88	9.93	285.00	7407.41	1.96	0.18	1.52
T_6	13.18	42.12	11.25	297.00	7530.86	2.33	0.19	1.66
T_7	9.16	32.76	8.70	247.52	6913.58	0.05	0.15	1.50
Mean	11.46	38.07	9.96	277.13	7365.08	1.18	0.17	1.56
SEm±	0.44	1.39	0.39	8.94	239.29	0.04	0.01	0.05
CD (p=0.05)	1.37	4.29	1.20	27.56	737.23	0.14	0.02	0.15

Table 2. Glutamine synthetase activity (μ mol g^{-1} min^{-1}) influenced by foliar application of nano-DAP in paddy

Treatments	Before 1st spray	After 1st spray	Before 2nd spray	After 2nd spray
T_1 – 100% RDF	0.12	0.19	0.78	0.91
T_2 – 100% RDF + one foliar spray of nano-DAP at 20-25 DAT	0.12	0.23	0.80	1.03
T_3 – 100% RDF + two foliar sprays of nano-DAP at 20-25 DAT and 45-50 DAT	0.14	0.24	0.98	1.29
T_4 – 100% NK + 75% P	0.10	0.18	0.67	0.70
T_5 – 100% NK + 75% P + one foliar spray of nano-DAP at 20-25 DAT	0.11	0.21	0.71	0.84
T_6 – 100% NK + 75% P + two foliar sprays of nano-DAP at 20-25 DAT and 45-50 DAT	0.11	0.22	0.73	1.06
T_7 – 100% NK + 0% P	0.07	0.12	0.45	0.57
Mean	0.11	0.20	0.73	0.91
SEm±	0.00	0.01	0.03	0.03
CD (p=0.05)	0.01	0.02	0.08	0.10

Table 3. Acid and Alkaline phosphatase activity (µ moles p-nitrophenol g^{-1} min^{-1}) influenced by foliar application of nano-DAP in paddy

Treatments	Acid phosphatase				Alkaline phosphatase			
	Before 1st spray	After 1st spray	Before 2nd spray	After 2nd spray	Before 1st spray	After 1st spray	Before 2nd spray	After 2nd spray
T_1	0.21	0.20	0.19	0.17	0.37	0.30	0.27	0.26
T_2	0.20	0.18	0.17	0.16	0.36	0.29	0.26	0.17
T_3	0.19	0.18	0.16	0.12	0.36	0.28	0.25	0.14
T_4	0.23	0.23	0.22	0.19	0.44	0.40	0.35	0.32
T_5	0.23	0.21	0.19	0.16	0.40	0.31	0.28	0.17
T_6	0.22	0.20	0.17	0.12	0.40	0.30	0.28	0.16
T_7	0.33	0.27	0.24	0.21	0.54	0.48	0.42	0.40
Mean	0.23	0.21	0.19	0.16	0.41	0.34	0.30	0.23
SEm±	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
CD (p=0.05)	0.21	0.20	0.19	0.17	0.37	0.30	0.27	0.26

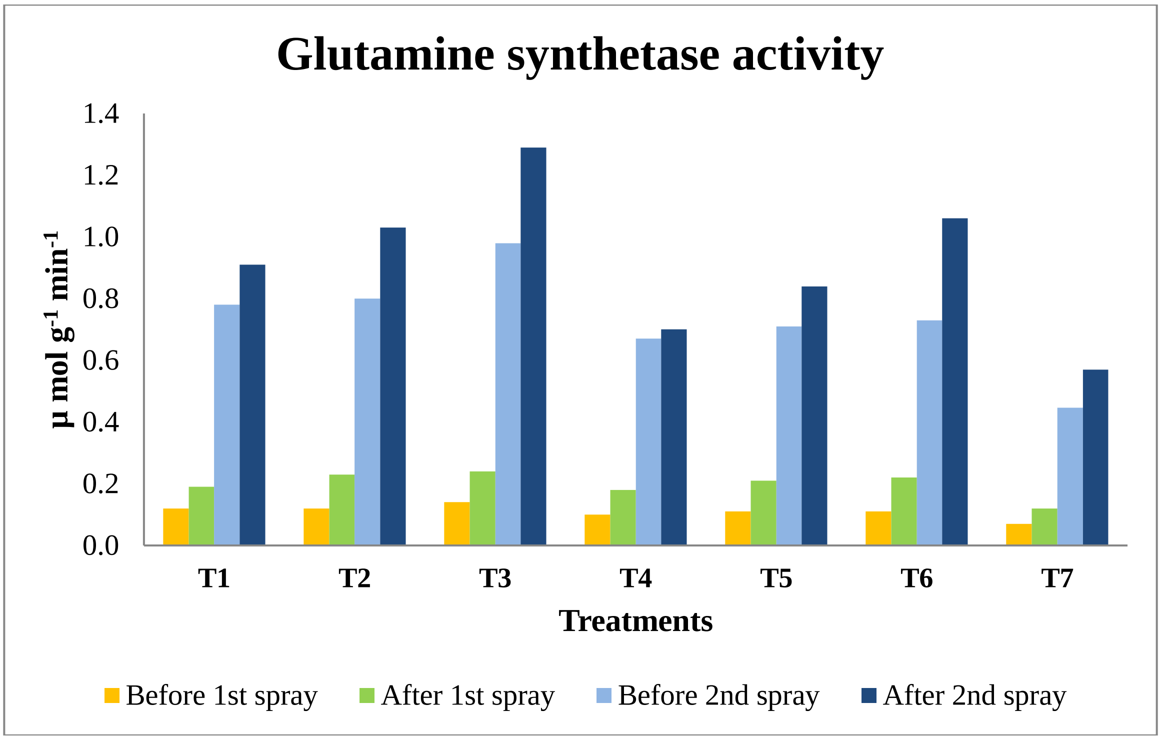

Fig. 1. The influence of nano-DAP on GS activity (μ mol g^{-1} min^{-1}) before and after foliar sprays in paddy

3.6 Number of Productive Tillers

Direct correlation exists between crop yield and tiller formation in rice [13]. In the absence of phosphorous (100% NK + 0% P) (T_7), the lowest number of productive tillers $hill^{-1}$ was recorded (8.70). Upon application of 100% NK + 75% P + two foliar sprays of nano-DAP during the tillering and PI stages (T_6), a significant increase (22.66%) has been observed (Table 1). This indicated that phosphorus deficiency can limit tiller initiation and development, disrupting the normal growth processes which significantly affects grain yield in paddy.

3.7 Number of Grains Panicle^{-1}

In paddy panicle contains spikelets which have the potential to develop into a grain. Results of the study reported that, under insufficient phosphorus conditions (T_7), the plant's ability to produce reproductive processes including grain formation can limit the plant's reproductive capacity, leading to a decreased number of grains $panicle^{-1}$. 100% NPK + two foliar sprays of nano-DAP (T_6) addition, ensured optimal reproductive development, resulting in a higher number of grains $panicle^{-1}$ (16.66%) and ultimately contributed to improved overall yield (Table 1). Similar increase in grains (446.7) was recorded by Kumar et al. [14].

3.8 Grain Yield (kg ha^{-1})

The maximum grain yield was achieved with application of 100% NK + 75% P and two foliar sprays of nano-DAP at tillering and PI stages (T_6). Lowest grain yield was observed in 100% NK + 0% P (T_7). In comparison to 100% RDF (T_1), the grain yield in 100% NK + 75% P+ two foliar sprays of nano-DAP (T_6) resulted in an increase of 8.19% (Table 1). Phosphorus deficiency severely impacts the overall growth and development of the plant by hindering key processes such as photosynthesis, energy transfer, nutrient uptake and reproductive development which are essential for the formation of grains. To optimize grain yield in paddy, it is essential to provide adequate supply of phosphorous to produce a healthy and abundant grain yield [4].

3.9 Nutrient Content in Plants

The N and P content was found to be maximum with the application of 100% NK + 75% P + two foliar sprays of nano-DAP (T_6) (2.33% and 0.19% respectively) at harvest, while K content (1.68%)

resulted in no significant difference (Table 1). NPK content in plants supports key biological processes such as photosynthesis, root development and energy transfer contributing to overall plant health and growth. Similar findings obtained by Poudel et al. [15].

4. CONCLUSION

The experimental study revealed that, with application of 100% NK along with 75% P and incorporating two foliar applications of nano-DAP during the tillering and panicle initiation stages led to a notable improvement in tiller count hill^{-1} (13.18), dry matter (42.12 g hill^{-1}), productive tillers hill^{-1} (11.25), number of grains panicle^{-1} (297), grain yield (7530.86 kg ha^{-1}) and NPK content (2.33%, 0.19% and 1.66% respectively). Biochemical parameters such as glutamine synthetase increased with fertilizer dosage and acid and alkaline phosphatase decreased with increased fertilizer dose. Combination of conventional and nano fertilizers produced superior growth and yield.

COMPETING INTERESTS

Authors have declared that they have no known competing financial interests or non-financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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