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Evaluating the efficacy of nano DAP on growth, yield, and quality of wheat

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Abstract

A field experiment was conducted during the *rabi* season of the year 2023-24 and 2024-25 at the Instructional Farm, Department of Agronomy, College of Agriculture, Junagadh Agricultural University, Junagadh. The experiment comprised of twelve treatments and was arranged in a randomized block design with three replications. The results indicated that the combined application of conventional and nano DAP positively influenced most growth and yield parameters of wheat. The results of the experiment indicated that significantly the highest grain yield (4986.56 kg/ha) and straw yield (6591.34 kg/ha) of wheat was recorded under application of 75% RDF + Foliar sprays of nano DAP @ 6 ml/lit at 30 and 45 DAS (T₁₁). Similarly, the yield attributes viz., plant height at 60 DAS (75.14 cm) and at harvest (90.27 cm), number of total tillers per m² at harvest (243.12), dry matter accumulation at harvest (18.05 g/plant), number of effective tillers per m² at harvest (222.45), spike length (9.20 cm) and number of spikelets per spike (18.44), number of grains per spike (50.09), grain weight per spike (2.10 g) and 1000 grain weight (50.82 g) at harvest of wheat crop were recorded significantly higher under treatment T₁₁. Different nano DAP treatments exerted their significant effect on quality parameters of wheat. The maximum protein content in wheat seeds (11.79%) was recorded in treatment T₁₁ i.e., 75% RDF + Foliar sprays of nano DAP @ 6 ml/lit at 30 and 45 DAS.

Keywords: Wheat, NANO DAP, yield, quality, growth, foliar sprays

1. Introduction

Following rice, wheat (*Triticum aestivum* L.) represents the most significant cereal crop in India regarding both total yield and land usage. Within India, the wheat crop is a vital component of the national food security framework, representing about 32% of the country's overall food grain production. During the 2024-25, India's wheat production reached 117.95 million tonnes across an area of 33.1 million hectares ^[1]. In Gujarat, wheat was cultivated over 13.07 lakh hectares, yielding 43.72 lakh tonnes ^[2].

Nano DAP is a nanotechnology-based fertilizer that provides Di-Ammonium Phosphate in the form of nanoparticles. A prominent example is IFFCO nano DAP, a liquid formulation containing 8% Nitrogen (w/v) and 16% Phosphorus (P₂O₅ w/v), engineered as a direct replacement for traditional granular DAP. With a particle size of less than 100 nm, nano DAP achieves over 80% nutrient use efficiency when applied as a foliar spray. Nano-fertilizers are specialized products designed to enhance nutrient delivery by utilizing particles engineered at the nanometer scale. Nano fertilizers have a large surface area, high sorption capacity and controlled-release kinetics to specific locations, making them a clever delivery mechanism ^[3]. This targeted delivery system enhances crop growth, yield and productivity while reducing soil contamination and reliance on conventional fertilizers. When nano fertilizers are used correctly, they may feed plants slowly, increases NUE, preventing leaching, minimising volatilization and lowering overall environmental hazards ^[4].

2. Materials and Methods

A field experiment entitled "Response of nano DAP on nutrient availability, growth and yield of wheat" was carried out during the *rabi* season of 2023-24 and 2024-25 at C-8 plot of the Instructional Farm, Department of Agronomy, College of Agriculture, Junagadh Agricultural University, Junagadh.

The experimental field consisted of an even topography with a gentle slope and good drainage. The experimental soil was medium black calcareous with clayey texture and slightly alkaline in reaction, low in available nitrogen, phosphorus, zinc and medium in available potassium as well as high in available sulphur, iron, manganese and copper. The weather conditions were favourable for crop growth and no severe attack of insect, pest and disease was recorded during the course of investigation. The wheat variety GJW-463 (Gujarat Junagadh Wheat-463) was developed and released in 2016 by Wheat Research Station, Junagadh Agricultural University, Junagadh, was used for this study. This is high yielding bread wheat variety for cultivation under early sown irrigated conditions of Saurashtra region and timely sown, irrigated conditions of rest of Gujarat.

The experiment comprised of twelve treatments viz., T₁: Absolute control, T₂: 100% RDF i.e., 120-60-60 N-P₂O₅-K₂O kg/ha, T₃: 75% RDF + Seed treatment with nano DAP @ 5 ml/kg of seed, T₄: 50% RDF + Seed treatment with nano DAP @ 5 ml/kg of seed, T₅: T₃ + Foliar sprays of nano DAP @ 3 ml/lit at 30 DAS, T₆: T₄ + Foliar sprays of nano DAP @ 3 ml/lit at 30 DAS, T₇: T₃ + Foliar sprays of nano DAP @ 6 ml/lit at 30 DAS, T₈: T₄ + Foliar sprays of nano DAP @ 6 ml/lit at 30 DAS, T₉: 75% RDF + Foliar sprays of nano DAP @ 3 ml/lit at 30 and 45 DAS, T₁₀: 50% RDF + Foliar sprays of nano DAP @ 3 ml/lit at 30 and 45 DAS, T₁₁: 75% RDF + Foliar sprays of nano DAP @ 6 ml/lit at 30 and 45 DAS, T₁₂: 50% RDF + Foliar sprays of nano DAP @ 6 ml/lit at 30 and 45 DAS and was arranged in a randomized block design with three replications. Nitrogen, phosphorus and potassium were applied in form of urea, DAP and MOP as per the treatment.

The data were subjected to statistical analysis by adopting appropriate analysis of variance as described by [5]. Wherever the F values found significant at 5% level of probability and the critical difference (CD) values was computed for making comparison among the treatment means. Pooled analysis of the wheat crop for two years was worked out as per the method described by Gomez and Gomez [5].

3. Results and Discussion

3.1 Plant Height

The application of 75% RDF + Foliar sprays of nano DAP @ 6 ml/lit at 30 and 45 DAS (T₁₁) showed significantly higher plant height at harvest (88.93, 91.60 and 90.27 cm) during both the years of experiments and in pooled analysis, respectively (Table 1). In two years and pooled data, treatment T₁₁ remained statistically at par with T₂, T₇ and T₉. On the other hand, the lowest plant height at harvest (68.68, 69.92 and 69.30 cm) was observed under treatment T₁ (Absolute control) in 2023-24 and 2024-25 as well as in pooled results, respectively.

The increase in plant height of wheat due to the application of nano DAP can be attributed to its tiny particle size (less than 100 nm). This small size allows for significantly higher nutrient absorption and better penetration through plant stomata when compared to conventional granular fertilizers. By delivering phosphorus and nitrogen directly to the plant's vascular system, nano DAP promotes faster cell division and elongation while enhancing photosynthetic activity. This high nutrient use efficiency ensures that the plant has a consistent energy supply for vertical growth resulting in taller and more robust wheat stalks with less fertilizer waste.

This outcome aligns with the results of [6].

3.2 Number of Total Tillers and Effective Tillers per m² at Harvest

Number of total tillers per m² (243.51, 242.74 and 243.12) and effective tillers per m² (224.78, 220.12 and 222.45) was found significantly higher with application of 75% RDF + Foliar sprays of nano DAP @ 6 ml/lit at 30 and 45 DAS (T₁₁) in both the years of experiments and in pooled analysis, respectively (Table 1) as compared to other treatments and was found to be at par with the treatments T₂, T₇ and T₉. In contrast, the lower number of total tillers (176.90, 173.36 and 175.13) and effective tillers (165.26, 160.86 and 163.06) was recorded with treatment T₁ (Absolute control) in 2023-24, 2024-25 and the pooled analysis, respectively.

Nano DAP increases the total wheat tillers and effective tillers by utilizing its microscopic particle size for rapid nutrient absorption which triggers meristematic activity where enhanced levels of phosphorus enhance cell division and the production of ATP, the primary energy molecule required for initiating new tiller buds. By increasing chlorophyll content and photosynthetic efficiency, the plant generates a greater supply of photosynthates that are translocated to the base of the plant to sustain multiple branches simultaneously.

Furthermore, the balanced nutrition provided by nano DAP supports the production of critical growth hormones and promotes robust root development, ensuring the plant has both the hormonal signalling and the root system to absorb enough water and minerals to support a significantly higher population of productive tillers per plant. These findings are in good agreement with those reported by [7].

3.3 Dry Matter Accumulation (g/plant) at Harvest

Among the various treatments, the application of 75% RDF + Foliar sprays of nano DAP @ 6 ml/lit at 30 and 45 DAS (T₁₁) gave significantly maximum dry matter per plant (17.53, 18.57 and 18.05 g/plant) during both years of experiment as well as in pooled analysis, respectively (Table 2) which found statistically equivalent to treatments T₂, T₇ and T₉ during 2023-24, 2024-25 and in pooled results, respectively. Whereas, the lowest dry matter accumulation per plant (12.23, 13.20, and 12.71 g) was recorded under T₁ (absolute control) in 2023-24, 2024-25 and the pooled analysis, respectively.

3.4 Length of Spike (cm)

The application of 75% RDF + Foliar sprays of nano DAP @ 6 ml/lit at 30 and 45 DAS produced significantly the highest spike length (9.16, 9.25 and 9.20 cm) in both 2023-24, 2024-25 and in pooled analysis, respectively (Table 2) which remained statistically at par with treatments T₂, T₇ and T₉ during 2023-24, 2024-25 and as well as in pooled analysis. The lower spike length (6.26, 6.35 and 6.31 cm) was observed in treatment T₁ (Absolute control).

Spike length is significantly increased as a result of the ultra-fine particle size of nano DAP which enables almost instantaneous absorption through the leaf cuticle and stomata. This provides the plant with a concentrated surge of bioavailable phosphorus precisely when it is required the most, which is during the critical stem elongation phase. This immediate energy boost directly stimulates rapid cell division and longitudinal expansion within the rachis that is

the wheat head's central axis by boosting ATP production and modulating growth-regulating hormones such as auxins and cytokinins resulting in a physically longer and more robust spike structure. These results are closely related to those described by [8].

3.5 Number of Spikelets per Spike

Among the various treatments imposed, the treatment T₁₁ i.e., 75% RDF + Foliar sprays of nano DAP @ 6 ml/lit at 30 and 45 DAS recorded significantly maximum number of spikelets per spike (17.67, 19.21 and 18.44) which was at par with treatments T₂, T₇ and T₉ in 2023-24, 2024-25 and pooled analysis, respectively (Table 2). Nevertheless, treatment T₁ (Absolute control) registered minimum number of spikelets per spike (11.67, 9.11 and 10.39).

The high phosphorus usage efficiency of nano nutrients during the early reproductive stage guarantees that the plant retains the required metabolic reserves to prevent the premature abortion of spikelet primordia. This results in a significant increase in the number of spikelets that are produced by each spike. By providing a steady and targeted supply of nutrients precisely during the differentiation of the floral organs, nano DAP enables the wheat plant to fully express its maximum genetic potential for the number of available grain sites along the spike. These results roughly coincide with the ones recorded by [9].

3.6 Number of Grains per Spike

With regard to observation application of 75% RDF + Foliar sprays of nano DAP @ 6 ml/lit at 30 and 45 DAS (T₁₁) recorded significantly maximum number of grains per spike (50.58, 49.60 and 50.09), which remained statistically at par with treatments T₂, T₇ and T₉ during 2023-24, 2024-25 and pooled analysis, respectively (Table 3). The treatment T₁ (Absolute control) gave minimum number of grains per spike (37.53, 37.56 and 37.54) in the both years of the study and pooled data. The number of grains per spike is improved as the efficient uptake and translocation of phosphorus and nitrogen through nano-delivery systems enhance pollen viability, tube growth and overall fertilization success. This drastically reduces floret sterility which is the common failure of flowers to turn into seeds by maintaining high metabolic energy levels and reducing oxidative stress during the sensitive pollination and anthesis windows ensuring that more initiated florets successfully develop into harvestable grains. These findings closely match those recorded by [10].

3.7 Grain Weight per Spike (g)

Among the various treatments imposed, the treatment T₁₁ i.e., 75% RDF + Foliar sprays of nano DAP @ 6 ml/lit at 30 and 45 DAS established its superiority by recording significantly highest grain weight per spike (2.09, 2.12 and 2.10 g), which remained at par with treatments T₂, T₇ and T₉ during 2023-24, 2024-25 and in pooled analysis, respectively. On the other hand, the lowest grain weight per spike (1.33, 1.36 and 1.35 g) was found in the T₁ (Absolute control) during both years of study and in pooled results (Table 3).

Grain weight per spike rises due to a significantly optimized "source-to-sink" relationship where the application of nano-scale nutrients improves chlorophyll density and delays leaf senescence (the aging of the plant). This "stay-green" effect maintains active photosynthesis for a longer duration

ensuring a continuous, robust and an uninterrupted flow of synthesized carbohydrates from the leaves (the source) into the developing spike (the sink) which collectively increases the total biomass of the grains held within each head. These results closely correspond with those documented by [11].

3.8 1000 Grain Weight (g)

Among different treatments, application of 75% RDF + Foliar sprays of nano DAP @ 6 ml/lit at 30 and 45 DAS (T₁₁) recorded significantly the highest 1000 grain weight (50.86, 50.78 and 50.82 g), which was at par with treatments T₂, T₇ and T₉ during 2023-24, 2024-25 and in pooled analysis, respectively. However, significantly lowest 1000 grain weight (39.69, 39.56 and 39.62 g) was registered under treatment T₁ (Absolute control) in 2023-24, 2024-25 and in pooled data, respectively (Table 3).

Test weight of wheat is substantially boosted because the rapid absorption and controlled release nature of nano particles facilitate a prolonged and highly efficient grain-filling period. By ensuring that the plant avoids a "nutrient crash" during the late stages of maturity, nano DAP allows for the maximum accumulation of starch, proteins and minerals within the endosperm resulting in individual grains that are noticeably denser, heavier, plumper and more uniform in size. These results were in close agreement with those found by [12].

3.9 Grain Yield

Application of 75% RDF + Foliar sprays of nano DAP @ 6 ml/lit at 30 and 45 DAS (T₁₁) significantly gave higher grain yield (5093.83, 4877.28 and 4986.56 kg/ha) in 2023-24, 2024-25 and pooled analysis, respectively (Table 4) as compared to the other treatments. However, it was found statistically at par with different treatments i.e., 100% RDF i.e., 120-60-60 N-P₂O₅-K₂O kg/ha (T₂), T₃ + Foliar sprays of nano DAP @ 6 ml/lit at 30 DAS (T₇) and 75% RDF + Foliar sprays of nano DAP @ 3 ml/lit at 30 and 45 DAS (T₉). While, treatment T₁ (Absolute control) for both years of the study and in pooled reported significantly lower grain yield (3385.32, 3067.61 and 3226.46 kg/ha), respectively.

The combined application of nano DAP with the recommended dose of fertilizer resulted in increased growth and yield parameters of wheat which led to higher wheat grain yields. The steady and extended supply of phosphorus and nitrogen supplied by nano DAP over the wheat growth period was a major contributing element to these results. In contrast to traditional DAP, nano DAP provides a longer-lasting release of phosphorus which more successfully promotes plant development.

Additionally, the immediate nitrogen and phosphorus requirements were successfully satisfied by nano DAP which triggered enzymatic activity and protein absorption pathways, increasing biomass production and crop growth rate. Grain yields were greater in the first year of the experiment than in the second, most likely as a result of more favourable weather that promoted ideal growth. This suggests that nano DAP is most effective under optimal environmental conditions. Furthermore, compared to soil fertilizer applications, foliar fertilization proved to be more effective under various conditions. Foliar fertilization delivers nutrients directly to the leaves, allowing for quicker absorption and reducing dependence on root activity and soil water availability. These findings align with previous studies of [13].

3.10 Straw Yield

Significantly higher straw yield of wheat (6762.35, 6420.33 and 6591.34 kg/ha) during 2023-24, 2024-25 and in pooled analysis, respectively was recorded with treatment T₁₁ (75% RDF + Foliar sprays of nano DAP @ 6 ml/lit at 30 and 45 DAS), though it remained statistically at par with treatments T₂ (100% RDF *i.e.*, 120-60-60 N-P₂O₅-K₂O kg/ha), T₇ (T₃ + Foliar sprays of nano DAP @ 6 ml/lit at 30 DAS) and T₉ (75% RDF + Foliar sprays of nano DAP @ 3 ml/lit at 30 and 45 DAS). Nevertheless, treatment T₁ (Absolute control) recorded the least amount of straw yield (4804.06, 4747.96 and 4776.01 kg/ha) throughout two years involved in the research and pooled, respectively (Table 4).

Nano DAP foliar spraying significantly increases wheat straw yield by utilizing ultra-small nanoparticles that rapidly penetrate leaf stomata and cuticles, bypassing the soil fixation issues common with conventional fertilizers and delivering nitrogen and phosphorus directly to the plant's metabolic centers. This immediate nutrient availability substantially boosts photosynthetic rates, chlorophyll content and enzymatic activity which accelerates the accumulation of dry matter and carbon assimilation essential for building vegetative biomass. Simultaneously, the precise delivery of these key nutrients stimulates the production of growth hormones like auxins and cytokinins leading to superior structural development characterized by significantly increased plant height, a higher number of effective tillers per square meter and a more voluminous root system that further enhances water and nutrient mining.

Ultimately, this optimized physiological state and high nutrient use efficiency (often exceeding 90%) result in a robust vegetative framework that directly translates into higher straw tonnage often matching or exceeding yields from full conventional fertilizer doses while using significantly less actual product. These findings agree with those of [14].

3.11 Protein Content in Grain (%)

The result revealed that the treatment T₁₁ (75% RDF + Foliar sprays of nano DAP @ 6 ml/lit at 30 and 45 DAS) recorded significantly higher protein content in wheat grain (11.74, 11.83 and 11.79%) than other treatments but was found statistically at par with the treatments T₂, T₇ and T₉ during 2023-24, 2024-25 and in pooled analysis, respectively (Table 4). Whereas, treatment T₁ (Absolute control) recorded the lower protein content of wheat grain (10.08, 9.99 and 10.04%) in 2023-24, 2024-25 and in pooled study, respectively.

Nano DAP increases wheat protein because its nanoscale particles penetrate leaves more efficiently than traditional fertilizers which boosts nitrogen use efficiency and activates key enzymes like nitrate reductase which are essential for converting nitrogen into amino acids. By providing a steady nutrient supply during the critical grain-filling stage, nano DAP ensures the plant has the energy (ATP) and raw materials needed to synthesize and store higher concentrations of protein within the grain. These findings align with the results reported by [15].

Table 1: Effect of different nano DAP treatments on plant height, number total and effective tillers of wheat at harvest

Tr. No.	Treatments	Plant height (cm) at harvest			Number total tillers per m ²			Number effective tillers per m ²		
		2023-24	2024-25	Pooled	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled
T ₁	Absolute control	68.68	69.92	69.30	176.90	173.36	175.13	165.26	160.86	163.06
T ₂	100% RDF <i>i.e.</i> , 120-60-60 N-P ₂ O ₅ -K ₂ O kg/ha	85.05	86.87	85.96	226.90	228.37	227.64	210.18	211.41	210.79
T ₃	75% RDF + Seed treatment with nano DAP @ 5 ml/kg of seed	78.03	81.51	79.77	211.33	207.06	209.20	195.86	190.72	193.29
T ₄	50% RDF + Seed treatment with nano DAP @ 5 ml/kg of seed	72.11	76.13	74.12	205.26	199.70	202.48	189.79	183.09	186.44
T ₅	T ₃ + Foliar sprays of nano DAP @ 3 ml/lit at 30 DAS	78.66	81.14	79.90	209.39	206.26	207.82	196.57	192.63	194.60
T ₆	T ₄ + Foliar sprays of nano DAP @ 3 ml/lit at 30 DAS	73.90	77.52	75.71	202.91	199.22	201.07	190.00	185.41	187.71
T ₇	T ₃ + Foliar sprays of nano DAP @ 6 ml/lit at 30 DAS	83.48	86.53	85.01	225.78	227.27	226.52	208.57	209.76	209.17
T ₈	T ₄ + Foliar sprays of nano DAP @ 6 ml/lit at 30 DAS	76.94	79.73	78.33	208.99	212.80	210.89	193.33	197.02	195.17
T ₉	75% RDF + Foliar sprays of nano DAP @ 3 ml/lit at 30 and 45 DAS	86.60	89.38	87.99	235.05	231.48	233.27	218.42	214.34	216.38
T ₁₀	50% RDF + Foliar sprays of nano DAP @ 3 ml/lit at 30 and 45 DAS	77.37	80.15	78.76	210.01	210.68	210.35	193.67	196.27	194.97
T ₁₁	75% RDF + Foliar sprays of nano DAP @ 6 ml/lit at 30 and 45 DAS	88.93	91.60	90.27	243.51	242.74	243.12	224.78	220.12	222.45
T ₁₂	50% RDF + Foliar sprays of nano DAP @ 6 ml/lit at 30 and 45 DAS	75.90	80.06	77.98	209.92	206.15	208.04	194.87	190.51	192.69
	S.Em.±	3.42	3.33	2.39	9.81	9.78	6.93	9.31	7.79	6.07
	C.D. at 5%	10.03	9.78	6.81	28.77	28.68	19.75	27.31	22.84	17.31
	C.V.%	7.51	7.07	7.29	7.95	7.99	7.97	8.13	6.88	7.54

Table 2: Effect of different nano DAP treatments on dry matter accumulation, spike length and number of spikelets per spike of wheat at harvest

Tr. No.	Treatments	Dry matter accumulation (g/plant)			Spike length(cm)			Number of spikelets per spike		
		2023-24	2024-25	Pooled	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled
T ₁	Absolute control	12.23	13.20	12.71	6.26	6.35	6.31	11.67	9.11	10.39
T ₂	100% RDF i.e., 120-60-60 N-P ₂ O ₅ -K ₂ O kg/ha	16.44	17.45	16.95	8.39	8.47	8.43	15.67	18.00	16.83
T ₃	75% RDF + Seed treatment with nano DAP @ 5 ml/kg of seed	14.82	15.62	15.22	7.79	7.87	7.83	14.33	13.89	14.11
T ₄	50% RDF + Seed treatment with nano DAP @ 5 ml/kg of seed	13.38	14.25	13.82	7.65	7.76	7.71	11.33	10.86	11.10
T ₅	T ₃ + Foliar sprays of nano DAP @ 3 ml/lit at 30 DAS	14.33	15.82	15.07	7.22	7.31	7.26	14.33	12.88	13.61
T ₆	T ₄ + Foliar sprays of nano DAP @ 3 ml/lit at 30 DAS	13.17	14.45	13.81	7.09	7.19	7.14	12.33	10.85	11.59
T ₇	T ₃ + Foliar sprays of nano DAP @ 6 ml/lit at 30 DAS	16.34	17.33	16.83	8.46	8.55	8.50	16.33	17.89	17.11
T ₈	T ₄ + Foliar sprays of nano DAP @ 6 ml/lit at 30 DAS	14.17	15.24	14.70	7.78	7.88	7.83	13.33	13.02	13.18
T ₉	75% RDF + Foliar sprays of nano DAP @ 3 ml/lit at 30 and 45 DAS	16.88	17.89	17.38	8.55	8.65	8.60	16.33	18.33	17.33
T ₁₀	50% RDF + Foliar sprays of nano DAP @ 3 ml/lit at 30 and 45 DAS	14.53	15.38	14.95	7.93	7.56	7.75	14.00	14.10	14.05
T ₁₁	75% RDF + Foliar sprays of nano DAP @ 6 ml/lit at 30 and 45 DAS	17.53	18.57	18.05	9.16	9.25	9.20	17.67	19.21	18.44
T ₁₂	50% RDF + Foliar sprays of nano DAP @ 6 ml/lit at 30 and 45 DAS	14.44	15.49	14.97	7.68	7.71	7.69	13.33	12.75	13.04
	S.Em.±	0.68	0.74	0.50	0.41	0.41	0.29	0.81	0.81	0.57
	C.D. at 5%	2.01	2.17	1.44	1.21	1.21	0.83	2.38	2.36	1.63
	C.V.%	7.97	8.07	8.03	9.13	9.08	9.10	9.86	9.81	9.83

Table 3: Effect of different nano DAP treatments on number of grains per spike, grain weight per spike and 1000 grain weight of wheat at harvest

Tr. No.	Treatments	Number of grains per spike			Grain weight per spike (g)			1000 grain weight (g)		
		2023-24	2024-25	Pooled	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled
T ₁	Absolute control	37.53	37.56	37.54	1.33	1.36	1.35	39.69	39.56	39.62
T ₂	100% RDF i.e., 120-60-60 N-P ₂ O ₅ -K ₂ O kg/ha	47.25	46.60	46.93	1.93	1.96	1.95	49.36	49.26	49.31
T ₃	75% RDF + Seed treatment with nano DAP @ 5 ml/kg of seed	41.31	40.96	41.13	1.64	1.66	1.65	46.37	46.24	46.30
T ₄	50% RDF + Seed treatment with nano DAP @ 5 ml/kg of seed	42.62	42.12	42.37	1.54	1.57	1.55	44.31	44.18	44.25
T ₅	T ₃ + Foliar sprays of nano DAP @ 3 ml/lit at 30 DAS	41.91	42.14	42.02	1.70	1.73	1.72	45.05	44.95	45.00
T ₆	T ₄ + Foliar sprays of nano DAP @ 3 ml/lit at 30 DAS	42.35	42.04	42.19	1.55	1.58	1.56	45.17	45.03	45.10
T ₇	T ₃ + Foliar sprays of nano DAP @ 6 ml/lit at 30 DAS	47.27	46.69	46.98	1.91	1.93	1.92	49.59	49.48	49.54
T ₈	T ₄ + Foliar sprays of nano DAP @ 6 ml/lit at 30 DAS	43.40	43.00	43.20	1.56	1.59	1.58	46.17	46.03	46.10
T ₉	75% RDF + Foliar sprays of nano DAP @ 3 ml/lit at 30 and 45 DAS	48.33	47.35	47.84	1.93	1.96	1.94	49.92	49.82	49.87
T ₁₀	50% RDF + Foliar sprays of nano DAP @ 3 ml/lit at 30 and 45 DAS	39.86	39.78	39.82	1.62	1.64	1.63	46.03	45.90	45.96
T ₁₁	75% RDF + Foliar sprays of nano DAP @ 6 ml/lit at 30 and 45 DAS	50.58	49.60	50.09	2.09	2.12	2.10	50.86	50.78	50.82
T ₁₂	50% RDF + Foliar sprays of nano DAP @ 6 ml/lit at 30 and 45 DAS	39.98	40.15	40.07	1.64	1.66	1.65	44.87	44.76	44.81
	S.Em.±	1.98	1.75	1.32	0.12	0.12	0.09	1.42	1.40	1.00
	C.D. at 5%	5.81	5.14	3.77	0.36	0.35	0.24	4.16	4.11	2.84
	C.V.%	7.88	7.04	7.47	12.40	12.10	12.25	5.29	5.23	5.26

Table 4: Effect of different nano DAP treatments on grain yield, straw yield and protein content of wheat

Tr. No.	Treatments	Grain yield (kg/ha)			Straw yield (kg/ha)			Protein content in grain (%)		
		2023-24	2024-25	Pooled	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled
T ₁	Absolute control	3385	3068	3226	4804	4748	4776	10.08	9.99	10.04
T ₂	100% RDF i.e., 120-60-60 N-P ₂ O ₅ -K ₂ O kg/ha	4584	4510	4547	6382	6214	6298	11.44	11.50	11.47
T ₃	75% RDF + Seed treatment with nano DAP @ 5 ml/kg of seed	4308	4202	4255	5747	5523	5635	10.52	10.70	10.61
T ₄	50% RDF + Seed treatment with nano DAP @ 5 ml/kg of seed	3981	3763	3872	5409	4937	5173	10.57	10.44	10.51
T ₅	T ₃ + Foliar sprays of nano DAP @ 3 ml/lit at 30 DAS	4373	4242	4307	5896	5582	5739	10.60	10.71	10.66
T ₆	T ₄ + Foliar sprays of nano DAP @ 3 ml/lit at 30 DAS	4073	3920	3996	5469	5124	5296	10.52	10.58	10.55
T ₇	T ₃ + Foliar sprays of nano DAP @ 6 ml/lit at 30 DAS	4657	4513	4585	6238	5918	6078	11.30	11.37	11.33
T ₈	T ₄ + Foliar sprays of nano DAP @ 6 ml/lit at 30 DAS	4249	4104	4177	5522	5314	5418	10.17	10.39	10.28
T ₉	75% RDF + Foliar sprays of nano DAP @ 3 ml/lit at 30 and 45 DAS	4862	4722	4792	6514	6294	6404	11.55	11.53	11.54
T ₁₀	50% RDF + Foliar sprays of nano DAP @ 3 ml/lit at 30 and 45 DAS	4213	4072	4143	5641	5237	5439	10.35	10.58	10.47
T ₁₁	75% RDF + Foliar sprays of nano DAP @ 6 ml/lit at 30 and 45 DAS	5094	4877	4986	6762	6420	6591	11.74	11.83	11.79
T ₁₂	50% RDF + Foliar sprays of nano DAP @ 6 ml/lit at 30 and 45 DAS	4282	4137	4210	5709	5462	5586	10.42	10.73	10.57
	S.Em.±	230	208	155	257	271	187	0.36	0.33	0.24
	C.D. at 5%	674	609	442	753	794	532	1.07	0.96	0.70
	C.V.%	9.17	8.62	8.91	7.61	8.43	8.01	5.84	5.22	5.53

4. Conclusion

From the results of two years experimentation, it can be concluded that the application of 75% RDF + Foliar sprays of nano DAP @ 6 ml/lit at 30 and 45 DAS exhibited its superiority in respect of all the parameters like growth parameters, yield attributes, yield and quality wheat. So, it can be suggested that the foliar application of nano DAP fertilizer in combination with conventional fertilizer showed potential in reducing the soil application of phosphorus.

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