



Effect of Nano DAP on Nitrogen, Phosphorus and Potassium Uptake by Grain, Straw and Total Plant of Wheat

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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 carried out at the Research Farm of the College of Agriculture, Indira Gandhi Krishi Vishwavidyalaya (IGKV), Raipur, Chhattisgarh, India, during the *Rabi* seasons of 2021–2022 and 2022–2023 to assess the effect of Nano DAP application on Nitrogen, Phosphorus and Potassium uptake by wheat grain, straw and total plant uptake. The experiment was laid

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out in a randomized block design comprising twelve treatments involving different application methods of conventional granular DAP and liquid Nano DAP. Nano DAP was applied through seed treatment and foliar spray. The results showed that total nitrogen uptake was recorded significantly higher in treatment T2- 100% NP through DAP (NPK 120: 60: 40 kg ha). Total phosphorus uptake was recorded significantly higher in treatment T2- 100% NP through DAP (NPK 120: 60: 40 kg ha), T7- 75% NP through DAP + Foliar Spray @ 0.2 % at 25-30 DAG with Nano DAP and T8- 75% NP through DAP + Seed Treatment @ 5 ml/kg seed + Foliar Spray @ 0.2 % at 25-30 DAG with Nano DAP. Total potassium uptake was recorded significantly higher in treatment T2, T7, T8, T12-75 % NP through DAP (NPK 90:45:40 kg/ha) and treatments in combination of 50% NP through DAP with Nano- DAP (T9 and T10). Lowest values of total nitrogen, phosphorus and potassium uptake were found in T11-Absolute Control (N0: P0: K0 kg/ha).

Keywords: Nano DAP; conventional DAP; nitrogen uptake; phosphorus uptake; potassium uptake; total uptake; wheat; grain and straw.

1. Introduction

“Nano DAP application promotes efficient nutrient utilization and supports sustainable rice production. Its application contributes to optimizing fertilizer use, reducing nutrient losses, and improving nutrient use efficiency, thereby supporting the maintenance of soil health and environmentally sustainable agricultural practices. The structural characteristics of nano-fertilizers, namely, their nanoscale dimensions and high specific surface area, significantly optimize nutrient use efficiency (NUE) through slow release, enabling maximal plant uptake while reducing nutrient loss. Nano DAP, being in liquid form, is more reliable for transportation and use. Management of phosphorus by nano-phosphatic fertilizer has great importance in wheat cultivation.

Recent work on wheat nutrition has described nano-fertilizers as potential supplements to conventional fertilizer inputs, although their performance depends on crop and application conditions (Syed *et al.*, 2024). A field study examining different nano-fertilizer combinations has also reported variation in productivity and nutrient-use efficiency across fertilizer treatments (Singh *et al.*, 2024). In a separate two-season wheat experiment, Nano DAP treatments were evaluated alongside graded phosphorus application rates, with differences in crop nutrient uptake and phosphorus-use efficiency among treatments (Reddy *et al.*, 2025).

Broader analyses of nanofertilizer use have highlighted the importance of formulation and application practices when evaluating nutrient delivery in agriculture (Ayenew *et al.*, 2025). Research on phosphorus fertilization in wheat has further shown that nutrient management can interact with crop development and soil processes (García-Díaz *et al.*, 2025). India has an area of 32.80 Mha for wheat having production of 117.94 million tonnes in 2024–25. During 2024–25, the yield of wheat was recorded at 1,599 kg/ha (Government of India, 2025). Nutrient management in wheat cultivation has great importance for the maintenance of soil health. Wheat is an exhaustive crop that depletes the soil nutrient content. Sustainable nutrient management is therefore essential to maintain soil health as well as crop productivity. Nano-fertilizers offer a promising approach to improving nutrient uptake, reducing nutrient losses and supporting sustainable wheat production.

However, the response of nitrogen, phosphorus and potassium uptake in wheat grain and straw to seed treatment and foliar application of Nano DAP combined with different rates of conventional DAP remains a specific question addressed by the present experiment. The objective of this study was to evaluate nitrogen, phosphorus and potassium uptake by wheat grain, straw and the total plant under different combinations of conventional DAP and Nano DAP application during the 2021–22 and 2022–23 Rabi seasons.

2. Materials and Methods

The experiment was conducted during the *Rabi* seasons of 2021–22 and 2022–23 at the research farm of Indira Gandhi Krishi Vishwavidyalaya (IGKV), Raipur, Chhattisgarh, India to evaluate the effects of Nano DAP application on wheat nutrient uptake, growth and yield. The experimental site was characterized by clayey-textured *Vertisol*, classified as a fine, montmorillonitic, hyperthermic *Chromustert*. The soil exhibited a slightly alkaline reaction, with a pH of 7.33, and had a normal electrical conductivity of 0.23 dS/m. Wheat variety ‘Amber’ was selected for the experiment, which was conducted using a Randomized Block Design comprising 12 treatments, each replicated three times. Different combinations of seed treatments and foliar spraying of Nano DAP with different doses of fertilizer and NP (0%, 50%, 75% and 100%) were applied through granular DAP in all treatments.

At harvest, wheat grain and straw samples were collected to quantify their primary macronutrient (NPK) concentrations (%). Total N content in the grain and straw was determined by micro Kjeldahl’s method given by Chapman and Pratt (1961). For estimation of P and K content in the grain and straw, 1.0 g of ground sample was digested at 250°C temperature with 10 ml of a di-acid mixture of HNO₃ and HClO₄ acids (ratio of 9:4). Phosphorus in aliquots of plant samples was estimated by vanadomolybdophosphoric yellow color method as described by Jackson (1973) and measured using a double-beam spectrophotometer Potassium in aliquots of plant samples was determined using a flame photometer as described by Chapman and Pratt (1961).

These values were then used to evaluate nutrient accumulation. Individual nutrient uptake was determined by multiplying the percentage concentration of each macronutrient by the corresponding grain and straw yields (q/ha). The overall nutrient removal by the crop was computed by adding the total accumulation from both the grain and straw.

Uptake of nutrient (kg ha^{-1}) = Nutrient Content (%) x Yield (q ha^{-1})

Total uptake (kg ha^{-1}) = uptake by grain (kg ha^{-1}) + uptake by straw (kg ha^{-1})

3. Results and Discussion

3.1 Nitrogen Uptake by Grain, Straw and Total Plant Uptake

Statistical analysis revealed that nitrogen uptake in wheat grain was significantly influenced by conventional DAP applications during the 2021–22 season. Specifically, T1 (0% NP), T12 (75% NP), and T2 (100% NP) treatments exhibited nitrogen uptake values of 20.22, 40.66, and 46.51 kg/ha , respectively, demonstrating a direct correlation between nitrogen uptake and increasing NP application rates. During the 2022–23 season, the maximum nitrogen accumulation (46.51 kg/ha) was achieved under T2 (100% NP), followed closely by T8 (75% NP + Nano DAP seed treatment @ 5 ml/kg + Nano DAP foliar spray @ 0.2% at 25–30 DAG) at 42.80 kg/ha . Notably, these two treatments were statistically at par with each other and significantly outperformed all other experimental groups.

The T8 treatment (75% NP + Nano DAP seed treatment @ 5 ml/kg + Nano DAP foliar spray @ 0.2% at 25–30 DAG) and T7 treatment (75% NP + Nano DAP foliar spray @ 0.2% at 25–30 DAG) registered nitrogen uptake values of 42.80 and 41.14 kg/ha , respectively. Statistical analysis indicated that both treatments were at par with each other, as well as with T12 (75% NP through conventional DAP). Crucially, these findings demonstrate that incorporating nano-fertilizer formulations can successfully reduce the required dose of conventional DAP by 25% without compromising grain nitrogen accumulation.

The present findings are in close agreement with those reported by Lahari *et al.* (2021). Poudel *et al.* (2023), reported that foliar supplementation with nano-phosphorus and nano-nitrogen in cereals enhanced nitrogen uptake within the straw fraction, highlighting the efficiency of nano-engineered formulations over conventional inputs.

A similar trend was recorded by Poudel *et al.* (2023) and Deo *et al.* (2022). Sahu *et al.* (2022) reported superior nutrient uptake within cereal matrices after foliar application of nano-fertilizers. This enhanced efficacy is highly correlated with the elevated surface area and minimal dimensions of the nanoparticles and these physical attributes facilitate rapid stomatal or cuticular penetration, thereby maximizing systemic absorption and internal nutrient utilization.

Nitrogen accumulation in wheat straw followed a highly consistent trend with that observed in the grain fraction. During the 2021–22 growing season, straw nitrogen uptake increased significantly in response to escalating application rates of nitrogen and phosphorus. Specifically, the 0% NP, 75% NP, and 100% NP treatment groups registered nitrogen uptake values of 10.01, 14.81, and 16.85 kg/ha , respectively, demonstrating a clear dose-dependent increase in nitrogen uptake. A corresponding trend was observed during the subsequent 2022–23 experimental cycle, where peak straw nitrogen accumulation was achieved under T2 (22.53 kg/ha). This was followed closely by T8 (22.38 kg/ha), T7 (21.74 kg/ha), and T12 (20.95 kg/ha). Conversely, the absolute control group generated the lowest straw nitrogen uptake at 11.05 kg/ha , representing a statistically distinct minimum compared to all fertilized treatments.

The cumulative nitrogen uptake by wheat (comprising both grain and straw fractions) during the 2021–22 and 2022–23 seasons demonstrated that the T2 (100% NP), T12 (75% NP), and nano-supplemented groups T7 and T8 (75% NP + Nano DAP) maintained statistical parity. The combined application of granular DAP along with Nano DAP formulations at 50–75% of the recommended NP dosage enhanced overall nitrogen accumulation, with a pronounced effect observed in the straw. Crucially, this integrated management strategy presents a viable pathway to curtail conventional chemical DAP applications by 25% without limiting crop nutrient uptake.

3.2 Phosphorus Uptake by Grain, Straw and Total Plant Uptake

During the 2021–22 season, wheat grain phosphorus uptake increased progressively with escalating conventional NP application rates, yielding values of 7.01, 13.75, and 15.06 kg/ha under T1 (0% NP), T12 (75% NP), and T2 (100% NP), respectively. In the 2022–23 cycle, peak grain phosphorus accumulation was achieved in T8 (18.43 kg/ha), followed by T2 (18.10 kg/ha) and T7 (17.49 kg/ha), and these three treatments were at par with each other. Conversely, the absolute control recorded a significantly lower phosphorus uptake of 8.19 kg/ha .

Phosphorus accumulation in wheat straw was considerably lower than that observed in the grain fraction. During the 2021–22 season, the application of conventional DAP at 0% (T1), 75% (T12), and 100% (T2) NP rates significantly enhanced straw phosphorus uptake, with recorded values of 1.13, 1.45, and 1.68 kg/ha , respectively. A parallel distribution pattern emerged during the 2022–23 cycle, where peak straw phosphorus accumulation was recorded under T2 (2.27 kg/ha), followed sequentially by T7 (1.95 kg/ha) and T8 (1.94 kg/ha). Notably, these results underscore that incorporating Nano DAP along with conventional DAP facilitated a 25% savings in conventional phosphate inputs. Conversely, the absolute control generated the minimum phosphorus uptake at 1.20 kg/ha .

Table 1. Effect of application of Nano DAP fertilizer on nitrogen uptake by grain, straw and total plant uptake 2021-22 and 2022- 23 (kg/ha)

Treatment details		Nitrogen uptake by grain (kg/ha)		Nitrogen uptake by straw (kg/ha)		Total uptake of Nitrogen by plant (kg/ha)	
		2021-22	2022-23	2021-22	2022-23	2021-22	2022-23
T1	0% NP (Control); N0: P0: K40 kg/ha	20.22e	21.00e	10.01cd	11.05c	30.23ef	32.04d
T2	100% NP through DAP (NPK 120: 60: 40 kg/ha)	46.51a	47.98a	16.85a	22.53a	63.35a	70.51a
T3	T1 + Seed Treatment @ 5 ml/kg seed with Nano DAP	24.12d	25.13d	11.03c	13.25bc	35.14de	38.38cd
T4	T1 + Seed Treatment @ 10 ml/kg seed with Nano DAP	26.14d	29.67d	11.52c	15.63b	37.66d	45.29c
T5	T1 + Foliar Spray @ 0.6 % at 25-30 DAG with Nano DAP	25.48d	28.43d	11.24c	15.36b	36.72d	43.79c
T6	T1 + Seed Treatment @ 5 ml/kg seed + Foliar Spray @ 0.6 % at 25-30 DAG with Nano DAP	25.66d	28.98d	11.40c	15.74b	37.06d	44.73c
T7	T12 + Foliar Spray @ 0.2 % at 25-30 DAG with Nano DAP	41.14b	44.85ab	16.06a	21.74a	57.20b	66.59a
T8	T12 + Seed Treatment @ 5 ml/kg seed + Foliar Spray @ 0.2 % at 25-30 DAG with Nano DAP	42.80ab	48.52a	15.63a	22.38a	58.43ab	70.89a
T9	50 % NP through DAP (NPK 60:30:40 kg/ha) + Foliar Spray @ 0.4 % at 25-30 DAG with Nano DAP	36.65c	39.07c	14.98a	20.76a	51.63c	59.83b
T10	50 % NP through DAP (NPK 60:30:40 kg/ha) + Seed Treatment @ 5 ml/kg seed + Foliar Spray @ 0.4 % at 25-30 DAG with Nano DAP	38.97bc	39.61bc	14.47b	19.43a	53.44bc	59.05b
T11	Absolute Control (N0: P0: K0 kg/ha)	19.63e	20.45e	9.07d	10.80c	28.70f	31.25d
T12	75 % NP through DAP (NPK 90:45:40 kg/ha)	40.66b	44.97a	14.81b	20.95a	55.47b	65.92ab
C.D. (0.05)		3.88	5.70	2.02	3.35	5.13	8.23

Table 2. Effect of application of Nano DAP fertilizer on phosphorus uptake by grain, straw and total plant uptake 2021-22 and 2022- 23 (kg/ha)

Treatment details		Phosphorus uptake by grain (kg/ha)		Phosphorus uptake by straw (kg/ha)		Total uptake of Phosphorus by plant (kg/ha)	
		2022	2023	2022	2023	2022	2023
T1	0% NP (Control); N0: P0: K40 kg/ha	7.01g	8.72f	1.13d	1.24c	8.14e	9.96f
T2	100% NP through DAP (NPK 120: 60: 40 kg/ha)	15.06a	18.10a	1.68a	2.27a	16.74a	20.37a
T3	T1 + Seed Treatment @ 5 ml/kg seed with Nano DAP	8.42f	10.43ef	1.29c	1.51c	9.71d	11.95ef
T4	T1 + Seed Treatment @ 10 ml/kg seed with Nano DAP	9.18e	12.57d	1.14d	1.56bc	10.32d	14.14d
T5	T1 + Foliar Spray @ 0.6 % at 25-30 DAG with Nano DAP	8.75ef	11.75de	1.23c	1.66b	9.97d	13.41de
T6	T1 + Seed Treatment @ 5 ml/kg seed + Foliar Spray @ 0.6 % at 25-30 DAG with Nano DAP	8.86e	12.07d	1.23c	1.69b	10.09d	13.76d
T7	T12 + Foliar Spray @ 0.2 % at 25-30 DAG with Nano DAP	13.77c	17.49ab	1.44b	1.95a	15.21c	19.44ab
T8	T12 + Seed Treatment @ 5 ml/kg seed + Foliar Spray @ 0.2 % at 25-30 DAG with Nano DAP	14.46b	18.43a	1.47b	1.94ab	15.93b	20.36a
T9	50 % NP through DAP (NPK 60:30:40 kg/ha) + Foliar Spray @ 0.4 % at 25-30 DAG with Nano DAP	13.16d	15.16c	1.29c	1.66b	14.45d	16.82c
T10	50 % NP through DAP (NPK 60:30:40 kg/ha) + Seed Treatment @ 5 ml/kg seed + Foliar Spray @ 0.4 % at 25-30 DAG with Nano DAP	13.24cd	15.50c	1.22cd	1.47c	14.46d	16.97c
T11	Absolute Control (N0: P0: K0 kg/ha)	6.45g	8.19g	1.02e	1.20c	7.47f	9.38g
T12	75 % NP through DAP (NPK 90:45:40 kg/ha)	13.75c	15.82bc	1.45b	1.76b	15.2c	17.58bc
C.D. (0.05)		0.56	1.86	0.12	0.38	0.61	2.11

Table 3. Effect of application of Nano DAP fertilizer on potassium uptake by grain, straw and total plant uptake 2021-22 and 2022- 23 (kg/ha)

Treatment details		Potassium uptake by grain (kg/ha)		Potassium uptake by straw (kg/ha)		Total uptake of Potassium by plant (kg/ha)	
		2022	2023	2022	2023	2022	2023
T1	0% NP (Control); N0: P0: K40 kg/ha	8.71cd	8.41de	66.34a	61.21a	75.05a	69.63b
T2	100% NP through DAP (NPK 120: 60: 40 kg/ha)	16.45a	15.47a	69.46a	69.85a	85.91a	85.32a
T3	T1 + Seed Treatment @ 5 ml/kg seed with Nano DAP	9.14c	10.41c	71.26a	67.99a	80.40a	78.39ab
T4	T1 + Seed Treatment @ 10 ml/kg seed with Nano DAP	9.86c	9.65cd	71.27a	70.99a	81.13a	80.64a
T5	T1 + Foliar Spray @ 0.6 % at 25-30 DAG with Nano DAP	9.41c	9.77c	70.85a	69.72a	80.26a	79.49a
T6	T1 + Seed Treatment @ 5 ml/kg seed + Foliar Spray @ 0.6 % at 25-30 DAG with Nano DAP	9.83c	10.23c	71.25a	69.80a	81.08a	80.02a
T7	T12 + Foliar Spray @ 0.2 % at 25-30 DAG with Nano DAP	14.94a	14.58ab	68.02a	67.30a	82.95a	81.89a
T8	T12 + Seed Treatment @ 5 ml/kg seed + Foliar Spray @ 0.2 % at 25-30 DAG with Nano DAP	15.50a	15.77a	69.12a	69.01a	84.62a	84.79a
T9	50 % NP through DAP (NPK 60:30:40 kg/ha) + Foliar Spray @ 0.4 % at 25-30 DAG with Nano DAP	13.70b	13.56b	67.48a	67.06a	81.18a	80.63a
T10	50 % NP through DAP (NPK 60:30:40 kg/ha) + Seed Treatment @ 5 ml/kg seed + Foliar Spray @ 0.4 % at 25-30 DAG with Nano DAP	14.65ab	13.86b	67.68a	67.66a	82.32a	81.51a
T11	Absolute Control (N0: P0: K0 kg/ha)	7.18d	7.05e	32.84b	32.07b	40.02b	39.11c
T12	75 % NP through DAP (NPK 90:45:40 kg/ha)	14.81a	14.74a	67.83a	67.05a	82.64a	81.79a
C.D. (0.05)		1.82	1.8	16.71	11.27	17.47	12.43

Total phosphorus uptake (grain + straw) during 2021–22 and 2022–23 peaked under T2 (100% NP), T12 (75% NP), and the nano-enhanced treatments T7 and T8 (75% NP + Nano DAP). Furthermore, treatments T2, T8, and T7 were at par with each other during the 2022–23 season.

3.3 Potassium Uptake by Grain, Straw and Total Plant Uptake

The results of potassium uptake by wheat grain in the 2021–22 period showed that applying NP at 0% (T1), 75% (T12), and 100% (T2) via conventional DAP significantly increased potassium accumulation. Uptake of potassium within the grain expanded along with rising doses of applied nitrogen and phosphorus, measuring 8.71, 14.81, and 16.45 kg/ha, respectively. Similar findings were documented during the 2022–23 season, where the highest potassium uptake by grain was recorded under T8 (15.77 kg/ha), followed by T2 (15.47 kg/ha), T12 (14.74 kg/ha), and T7 (14.58 kg/ha). All these treatment combinations were observed to be statistically at par with each other, demonstrating a potential saving of 25% of the dose of conventional chemical fertilizer. Conversely, the minimum potassium uptake by grain (7.18 kg/ha) was consistently produced by the absolute control treatment (T11).

The results of potassium uptake by wheat straw in the 2021–22 period showed that applying NP at 0% (T1), 75% (T12), and 100% (T2) significantly increased potassium accumulation. Uptake of potassium within the straw matrix expanded along with rising doses of applied nitrogen and phosphorus, measuring 66.34, 67.83, and 69.46 kg/ha, respectively. Similar findings were documented during the second year of the experiment. Among all tested combinations, treatments T1 to T10 and T12 were observed to be statistically at par with each other, generating a straw potassium uptake range of 61.21–70.99 kg/ha, whereas the absolute control (T11) recorded the significantly lowest value.

Consistent with these observations, several researchers have documented analogous patterns of phosphorus uptake in response to variable phosphorus fertilization levels in cereal crops. The occurrence of uniform nutrient accumulation resulting from equivalent application rates aligns directly with the earlier findings of Abdolzadeh *et al.* (2010) and Poudel *et al.* (2023).

The data on total potassium uptake by wheat (grain + straw) showed that during the 2021–22 period, increasing nitrogen and phosphorus application rates elevated total potassium accumulation. Total potassium uptake expanded alongside rising doses of applied NP at 0%, 75%, and 100%, with values of 75.05, 81.79, and 85.91 kg/ha, respectively, with non-significant variations observed among these treatments. Parallel findings were documented during the second year of the experiment (2022–23). Excluding the absolute control (T11), treatments T1 to T10 and T12 recorded almost identical total plant potassium uptake values ranging from 78.39 to 85.32 kg/ha. All of these treatment groups were found to be significantly superior to the absolute control, which recorded the lowest total uptake at 40.02 kg/ha.

4. Conclusion

The two-year field experiment demonstrated that nitrogen, phosphorus and potassium uptake by wheat grain, straw and the total plant varied according to conventional DAP application rates and their combinations with Nano DAP. The treatment receiving 100% conventional NP through DAP (T2) generally produced high nutrient uptake, while the combined application of 75% conventional NP with Nano DAP foliar spraying (T7), or with both seed treatment and foliar spraying (T8), produced comparable results for several nutrient-uptake measurements. During 2022–23, total nitrogen uptake was 70.51 kg/ha under T2 and 70.89 kg/ha under T8, while corresponding phosphorus uptake was 20.37 and 20.36 kg/ha, respectively. Total potassium uptake also remained comparatively high under these treatments. In contrast, the absolute control consistently recorded the lowest total nutrient uptake. The findings suggest that supplementing reduced conventional DAP application with Nano DAP may offer an alternative nutrient-management approach for wheat cultivation under the investigated conditions. However, the observed responses were treatment-specific, and the findings should be interpreted within the experimental conditions. Further evaluation under different soil and growing conditions would help establish the wider applicability of these results.

5. Limitations

The study was conducted at a single experimental location during two consecutive *Rabi* seasons using one wheat variety, which limits the generalization of the findings to other soil types, climatic conditions and cultivars. The experimental comparisons focused on specified combinations of conventional DAP and Nano DAP applied through seed treatment and foliar spraying. Consequently, the findings may not represent responses to other application schedules or fertilizer formulations. The results should therefore be interpreted within the investigated treatment combinations, experimental location and study period.

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Declaration of AI Use

This manuscript was prepared through the intellectual contributions of the author(s) to the study design, data analysis, interpretation of results, and scholarly content. Grammarly and ChatGPT were used solely to assist with grammatical refinement and reference

formatting during manuscript revision. The author(s) accept full responsibility for the accuracy, integrity, and final content of the manuscript.

Competing Interests

Authors have declared that no competing interests exist.

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