International Journal of Advanced Biochemistry Research

ISSN Print: 2617-4693
ISSN Online: 2617-4707
NAAS Rating (2025): 5.29
IJABR 2025; SP-9(11): 1311-1316
www.biochemjournal.com
Received: 01-08-2025
Accepted: 04-09-2025

Deepika Sahu
Department of Soil Science and Agricultural Chemistry, College of Agriculture IGKV, Raipur, Chhattisgarh, India

Rakesh Banwasi
Department of Soil Science and Agricultural Chemistry, College of Agriculture IGKV, Raipur, Chhattisgarh, India

LK Shrivastava
Department of Soil Science and Agricultural Chemistry, College of Agriculture IGKV, Raipur, Chhattisgarh, India

Manisha Sahu
Department of Farm Machinery and Power Engineering, College of Agriculture IGKV, Raipur, Raipur, Chhattisgarh, India

Corresponding Author:
Deepika Sahu
Department of Soil Science and Agricultural Chemistry, College of Agriculture IGKV, Raipur, Chhattisgarh, India

Effect of Nano-DAP on growth parameters and yield attributes of wheat

Deepika Sahu, Rakesh Banwasi, LK Shrivastava and Manisha Sahu

DOI: https://www.doi.org/10.33545/26174693.2025.v9.i11Sq.6425

Abstract
Nanotechnology is a cutting-edge science used to improve productivity of crops and efficiently regulate delivery of nutrients to plants and targeted sites to increase nutrient use efficiency over traditional fertilizer. Therefore, to evaluate the effect of Nano DAP on wheat growth parameters and yield attributes a field experiment was conducted in research farm, IGKV, Raipur, Chhattisgarh, India during *rabi* seasons of 2021-22 and 2022-23. This experiment was laid out with 12 treatments and 3 replications of wheat in randomized block design. The results revealed that in treatments (T_2) 100% NP through DAP (NPK as RDF @ N_{120}: P_{60}: K_{40} and (T_8) 75% NP through DAP + ST (Seed Treatment) with N-DAP @ 5 ml/kg seed + FS (Foliar Spray) with Nano DAP @ 0.2% at 25-30 DAG (Days After Growing) obtained significantly higher plant height at harvest 86.90 cm and 87.48 cm in 2021-22 and 85.75 cm and 85.39 cm in 2022-23 respectively compared to control plot (72.24 cm in 2021-22 and 70. 50 cm in 2022-23). Ear heads per meter square in both years showed highest value in treatment (T_2) which was at par with T_8 (291.00, 290.00 respectively). No significant difference was observed among treatments during both seasons for spike length, spike weight and test weight. The results revealed that 25% of conventional DAP fertilizer can be saved by application through combination of nano DAP fertilizer with DAP in wheat and long-term application of Nano DAP can improve soil health.

Keywords: Nano DAP (liquid), DAP, wheat, growth parameters, foliar application, seed treatment, yield attributes

Introduction
The application of nanotechnology in form of nanofertilizer provides an innovative, efficient, and eco-friendly alternative to synthetic fertilizers. The nanofertilizers allow a slow and sustained release of nutrients that not only supports plant growth but also conserve the diversity of the beneficial microbiome. Such attributes may help the phytomicrobiome to efficiently mitigate both biotic and abiotic stress conditions. Unfortunately, despite exceptional efficiency and ease of applications, certain limitations are also associated with the nanofertilizers such as their complicated production process, tenuous transport and dosage-sensitive efficiency. These bottlenecks are causing a delay in the large-scale applications of nanofertilizers in agriculture (M. Kalwani *et al.* 2022) [13].

Nano fertilizer had a positive impact on the Agri-food Sector minimizing problems on environment, human health, thus improving food security and productivity. Nano-materials may help to improve nutrient use efficiency because of their small size, more surface area and their slow rate of release, which facilitates the plants to take up most of the nutrients without any waste. Nano Urea Liquid received brilliant response from the farmers and stakeholders around the country (Kumar, Kiran and Samal) [15, 14] and during the period of 1st april, 2022 to 10th august, 2022 nano urea production and dispatches had been 1.23 crore bottles its production touched 1.5 lakh bottles per day.

Looking to the significant results of nano-urea in the crops, new experiments on other nano fertilizers has also been started in the country. Nano-DAP as nano-phosphatic fertilizer developed by the IFFCO. Nano-DAP being in liquid form is more reliable to transportation and use. Management of P via nano-phosphatic fertilizer may be of great importance in the rice-wheat cropping system. The field experiments are needed to study the effect of Nano-DAP on the performance of agricultural crops as very few information is available on the performance of Nano-phosphatic fertilizer.

Rice and wheat grown sequentially in an annual rotation constitute most widely adopted cropping system in India. The rice-wheat cropping system is one of the world's largest agricultural production systems, occupying 26 Mha of cultivated land in the Indo-Gangetic Plains and in China. The rice-wheat system comprises about 13 Mha in area in the Indo-Gangetic Plains, of which the Indian part of IGP comprises about 10 Mha (Timsina and Connor, 2001) [19]. In India, the production of rice and wheat grains during the year of 2020-21 was 121.46 million tons and 108.76 million tons, respectively (Ministry of Agriculture and Farmers Welfare 2020-21). Wheat covers area of .315 Mha area with production and productivity of 0.259 MT and 8.22 q/ha. (Agriculture statistics table year 2021, Chhattisgarh Government). Nutrient management in the rice-wheat cropping system have great importance for the maintenance of soil health. Both rice and wheat are exhaustive feeders, and this double cropping system is heavily depleting the soil of its nutrient content.

Materials and Methods

The experiment was conducted at research farm of Indira Gandhi Krishi Vishwavidyalaya (IGKV), Raipur, Chhattisgarh, India during *Kharif* and *Rabi* season of the year 2020-21 and continued to 2022-23 to investigate the response of nano DAP application on the growth and yield of rice and wheat. The soil of the experimental area was clayey in nature falling under the category of *Vertisol*, which is a fine, hyperthermic, montmorillonitic chromustert soil. The experimental soil was clayey in texture, slightly alkaline (7.33) and normal in nature (0.23 dS m^{-1}). Wheat (variety-Amber) was used as test crop in the experiment. The trial was laid down in a randomized block design (RBD) corresponding to 12 treatments and three replications.

All the treatments consisted of a common dose of 0%, 50%, 75% and 100% recommended dose of NP through DAP in wheat. Urea, DAP, Muriate of potash (MOP) and nano DAP were used as fertilizers. The urea, DAP and MOP were administered through soil application as basal and split dose whereas, nano DAP was given 2 times (at tillering and panicle initiation stage) through foliar application, as per the treatments. For agronomic observations, five to ten hills at random from each plot were selected and their mean was noted as the final reading of the respective plot.

Results and Discussion

Growth parameters

The results of plant height of wheat in the year 2021-22 showed that during the different stages of crop growth at 30, 60, 90 DAG and at harvest of wheat crop, plant height was significantly affected by application of phosphorous and nitrogen and significantly increased with increasing dose of DAP (0%, 75% and 100% NP). Among all the treatments, treatment T_2 (100% NP through DAP as NPK @ 120: 60: 40 kg ha^{-1}) was recorded maximum plant height at initial stage of crop, at 30, 60, 90 DAG and respectively recorded the plant height 46.06, 78.80, 85.73 cm at 30, 60, 90 DAG. At the harvest of wheat crop. treatment T_8 (75% NP + Foliar Spray @ 0.2% at 25-30 DAG with Nano DAP) recorded 86.90 cm plant height.

At all different stages of crop growth at 30, 60, 90 DAG and at harvest of wheat crop, treatments T_8 (75% NP + Foliar Spray @ 0.2% at 25-30 DAG with Nano DAP) and T_7 (75% NP + Seed Treatment @ 5 ml/kg seed + Foliar Spray @ 0.2% at 25-30 DAG with Nano DAP) both the treatments were observed at par plant height with T_2 (100% NP through DAP as NPK @ 120: 60: 40 kg ha^{-1}) and found best for the saving of 25% conventional DAP. Among all the treatments, lowest plat height was observed with the T_{11} (No NPK) in all the stages.

Results of effect of Nano DAP on plant height of wheat in the year 2022-23 was observed similar as observed in the year 2021-22.

Yield attributes

Ear head per meter square (No.)

The results of numbers of ear heads of wheat per meter square for the year 2021-22 showed that the treatments of phosphorous and nitrogen significantly affect the numbers of ear heads of wheat per meter square. The data showed increase in the numbers of ear heads of wheat per meter square with increasing dose of DAP from 0% (T_1), 75% (T_{12}) and 100% NP (T_2) and respectively recorded 270.00, 293.00 and 298.00 ear heads.

Among all the treatments, maximum number of ear heads 298.00 was recorded in T_2 (100% NP through DAP as NPK @ 120: 60: 40 kg ha^{-1} 100% NP) which was closely followed by 297.33 in T_7 (75% NP + Foliar Spray @ 0.2% at 25-30 DAG with Nano DAP with Nano DAP) followed by 296.33 in T_8 (75% NP + Seed Treat with Nano DAP @ 5 ml/kg seed + Foliar Spray @ 0.2% at 25-30 DAG). Treatments T_7 and T_8 were found at par ear heads with T_2 (100% NP). And showed 25% saving of DAP.

Treatments T_9 and T_{10} where Nano DAP applied as seed treatment and foliar spray with 50% NP through DAP were recorded at par ear heads (291.33-292.33) with the treatment of 75% NP (293.00) and also showed 25% saving of DAP fertilizer. Treatments T_3 and T_4 (Seed Treatment @ 5 ml/kg seed or @ 10 ml/kg seed with Nano DAP) and T_5 (Foliar Spray @ 0.6% at 25-30 DAG with Nano DAP) and T_6 (Seed Treatment @ 5 ml/kg seed + Foliar Spray @ 0.6% at 25-30 DAG with Nano DAP) were recorded at par ear heads (281.67-282.67) with each other which showed no variation among these treatments. Treatments T_3, T_4, T_5 and T_6 were found significant superior over T_1 and found beneficial if no NP were applied in the field (0% NP). Among all the treatments, absolute control (T_{11}-No NPK) recorded significant lowest number of ear heads (263.67).

Increasing in the number of ear head was observed due the balanced nutrition in the wheat. Al-Juthery *et al.* (2018) [3] and Adhikari *et al.* (2017) [2] also worked on effect of nano-phosphorous on wheat and reported that application of higher dose of P significantly increased the numbers of ear heads per meter square of wheat. Similar results of effect of nano-DAP on numbers of ear heads of wheat per meter square was also observed in year 2022-23.

Spike length (cm)

The results of effect of Nano-DAP on spike length of wheat was found non-significant in the year 2021. Although the length of spike of wheat in the treatment of 0% NP (T_1), 75% NP (T_{12}) and 100% NP (T_2) were showed a trend of increasing with increasing dose of phosphorous (0%-100% NP), no statistically significant variation on length of spike were observed. Among all the treatments, Maximum length 8.66 cm was found in T_2 whereas minimum length 8.10 cm was observed with T_{11} (absolute control). Similar results of

effect of nano-DAP on length of spikes of wheat as found in 2021-22 was also observed in year 2022-23. Similar results in the wheat were reported by Al-Juthery *et al.* (2018) [3], Amanullah (*et al.* 2022) [6] also gave similar results on spike length.

Spike weight (g)

The results of effect of Nano-DAP on spike weight of wheat were found non-significant in the year 2021. Although the weight of per spike of wheat in the treatment of 0% NP (T_1), 75% NP (T_{12}) and 100% NP (T_2) were showed a trend of increasing with increasing dose of phosphorous (0%-100% NP), no statistically significant variation on weight of spike were observed. Among all the treatments, Maximum weighT_1.60 gm was found in T_2 whereas minimum weighT_1.12 gm was observed with T_{11} (absolute control). Similar results of effect of nano-DAP on weight of spikes of wheat as found in 2021-22 was also observed in year 2022-23. Similar results in the spike weight were reported by Bhaktiar *et al.* (2017) [5].

Test weight (g)

The results of effect of Nano-DAP on test weight of wheat grains was found non-significant in the year 2021-22. Although the test weight of grain in the treatment of 0% NP (T_1), 75% NP (T_{12}) and 100% NP (T_2) were showed a trend of increasing weight (35.43-40.06 gm) with increasing dose of phosphorous (0% NP-100% NP), no statistically significant variation on length of spike were observed.

Among all the treatments, Maximum test weight 40.06 gm was found in T_2 whereas minimum test weight 35.11 gm was observed with T_{11} (absolute control). Similar results of effect of Nano-DAP on test weight of grain of wheat which was found in 2021-22 was also observed in year 2022-23.

A non-significant increase in the test weight of grain due to application of increasing doses of phosphorous were observed. Similar test weight of the grains on various treatments was observed maybe due to the varietal/genetic character of the wheat which showed no changes. Similar result was also reported by Sorour *et al.* (2017) they found that test weight of cereals was at par when phosphorous was applied on cereal crop through the Single Super Phosphate in the soil and Nano-phosphorous through the foliar spray.

Grain Yield

The results of grain yield of wheat during 2021 (Table-4) showed that application of NP @ 0% (T_1), 75% (T_{12}) and 100% (T_2) through the conventional or granular DAP, were significantly increased the yield with increasing dose of nitrogen and phosphorous (0%-100% P) and respectively recorded the straw yield 12.80, 27.54 and 31.65 q/ha.

Among all the treatments (T_1-T_{12}), maximum yield 31.65 q/ha was obtained with T_2 (100% NP through DAP as NPK @ 120: 60: 40 kg ha^{-1}) followed by 29.80 q/ha was recorded with T_8 (75% NP through DAP + Seed Treatment @ 5 ml/kg seed + Foliar Spray @ 0.2% at 25-30 DAG with Nano DAP). Both the treatments were found at par with each other, which showed that application of Nano DAP as Seed Treatment @ 5 ml/kg seed + Foliar Spray @ 0.2% at 25-30 DAG with 75% NP through DAP responded best among all the application of Nano-DAP and showed 25% saving of DAP fertilizer.

Phosphorous as a major plant nutrient increase the root growth of the plant and support the uptake of the nutrients and increase the production of grain. Increasing in the grain yield due to increasing in the dose of P was also reported by many scientists. Abdel-Aziz *et al.* (2019) [1], Amanullah *et al.* (2020) [6], Hena rani *et al.* (2021) [8], Laheri *et al.* (2021) [16] and Meena *et al.* (2022) [17] also worked on effect of phosphorous on rice and reported that application of higher dose of P significantly increased the yield of cereal crop.

Among all the treatments (T_1-T_{12}). Treatment of absolute control (T_{11}-No NPK) recorded significant lowest yield (12.31 q/ha). Almost similar trends and results of application of Nano-DAP on grain yield of wheat were also found in the year 2022-23.

Straw Yield

Like the grain yield of wheat, data of straw yield of wheat (Table-4.24) also showed a trend of significantly increase in the yield with increasing dose of nitrogen and phosphorous (0%-100% NP). Application of NP @ 0% (T_1), 75% (T_{12}) and 100% (T_2) through the conventional or granular DAP, were respectively, recorded the straw yield 16.82, 31.25 and 36.12 q/ha.

Among all the treatments (T_1-T_{12}), maximum yield 36.12 q/ha was obtained with T_2 (100% NP through DAP as NPK @ 120: 60: 40 kg ha^{-1}) followed by 33.97 q/ha in T_8 (75% NP through DAP + Seed Treatment @ 5 ml/kg seed + Foliar Spray @ 0.2% at 25-30 DAG with Nano DAP) and 33.48 q/ha in T_7 (75% NP through DAP + Foliar Spray @ 0.2% at 25-30 DAG with Nano DAP) were recorded. All these treatments were recorded at par with each other. Treatments T_7 and T_8 were also observed best among all the treatments of Nano-DAP and showed 25% saving of DAP fertilizer.

Treatments T_9 and T_{10} where Nano DAP were applied with 50% NP through DAP were recorded at par straw yields (27.40-28.65 q/ha) with the treatment T_{12} (75% NP) and also showed 25% saving of DAP fertilizer.

Treatments T_3 and T_4 (Seed Treatment @ 5 ml/kg seed or @ 10 ml/kg seed with Nano DAP) and T_5 (Foliar Spray @ 0.6% at 25-30 DAG with Nano DAP) and T_6 (Seed Treatment @ 5 ml/kg seed + Foliar Spray @ 0.6% at 25-30 DAG with Nano DAP) were recorded at par grain yield (15.84-17.59 q/ha) with each other which showed no variation among these treatments. Treatments T_4, T_5 and T_6 were found significant superior over T_1 and found beneficial if no NP were applied (0% NP).

Among all the treatments, absolute control (T_{11}-No NPK) recorded significant lowest straw yield (15.32 q/ha). Data of straw yield of wheat in the year 2022-23 (Table-4.24) also showed increasing trend with increasing dose of NP as observed in 2021-22.

Table 1: Effect of application of Nano-DAP fertilizer on plant height (cm) of wheat during 2021-22 and 2022-23

Treatment Details		Plant Height (cm.) 2021-22				Plant Height (cm.) 2022-23			
		30 DAT	60 DAT	90 DAT	At Harvest	30 DAT	60 DAT	90 DAT	At harvest
T_1	0% NP (Control); N0: P0: K40 kg ha^{-1}	32.66	63.91	69.60	74.42	16.6	62.55	68.71	73.28
T_2	100% NP through DAP (NPK 120: 60: 40 kg ha^{-1})	46.06	78.80	85.73	86.90	31.05	77.25	85.26	85.75
T_3	T_1 + Seed Treatment @ 5 ml/kg seed with Nano DAP	33.09	67.13	70.61	75.57	45.25	65.64	70.15	74.14
T_4	T_1 + Seed Treatment @ 10 ml/kg seed with Nano DAP	33.21	66.20	72.05	76.41	32.81	66.25	71.59	74.38
T_5	T_1 + Foliar Spray @ 0.6% at 25-30 DAG with Nano DAP	33.13	66.82	72.67	75.97	31.58	66.30	72.20	74.03
T_6	T_1 + Seed Treatment @ 5 ml/kg seed + Foliar Spray @ 0.6% at 25-30 DAG with Nano DAP	33.17	67.35	73.31	76.19	32.20	66.83	72.83	74.57
T_7	T_{12} + Foliar Spray @ 0.2% at 25-30 DAG with Nano DAP	43.72	76.42	84.47	87.36	32.50	75.90	84.00	84.70
T_8	T_{12} + Seed Treatment @ 5 ml/kg seed + Foliar Spray @ 0.2% at 25-30 DAG with Nano DAP	44.84	77.01	84.9	87.48	44.00	76.49	84.50	85.39
T_9	50% NP through DAP (NPK 60:30:40 kg ha^{-1}) + Foliar Spray @ 0.4% at 25-30 DAG with Nano DAP	34.41	67.56	75.05	78.31	44.49	66.37	74.56	75.37
T_{10}	50% NP through DAP (NPK 60:30:40 kg ha^{-1}) + Seed Treatment @ 5 ml/kg seed + Foliar Spray @ 0.4% at 25-30 DAG with Nano DAP	34.40	69.28	77.24	79.40	34.57	68.76	76.73	77.26
T_{11}	Absolute Control (N0: P0: K0 kg ha^{-1})	29.23	62.15	67.74	72.24	36.76	61.37	67.30	70.50
T_{12}	75% NP through DAP (NPK 90:45:40 kg ha^{-1})	43.03	75.88	82.50	85.16	29.27	75.03	83.02	83.63
	C.D. (0.05)	6.62	1.97	1.65	2.43	6.62	6.09	4.38	4.48
	C.V.%	2.26	5.77	4.83	7.13	2.26	2.08	1.92	2.01

Table 2: Effect of application of Nano-DAP fertilizer on numbers of ear heads per meter square (Nos.) of wheat 2021 and 2022

Treat	Treatment details	Ear head per meter square (Nos.)		
		2021	2022	Mean
T_1	0% NP (Control); N0: P0: K40 kg ha^{-1}	270.00	260.67	265.33
T_2	100% NP through DAP (NPK 120: 60: 40 kg ha^{-1})	298.00	284.00	291.00
T_3	T_1 + Seed Treatment @ 5 ml/kg seed with Nano DAP	281.67	269.67	275.67
T_4	T_1 + Seed Treatment @ 10 ml/kg seed with Nano DAP	283.00	276.00	279.50
T_5	T_1 + Foliar Spray @ 0.6% at 25-30 DAG with Nano DAP	282.33	271.3	276.83
T_6	T_1 + Seed Treatment @ 5 ml/kg seed + Foliar Spray @ 0.6% at 25-30 DAG with Nano DAP	282.67	273.00	277.83
T_7	T_{12} + Foliar Spray @ 0.2% at 25-30 DAG with Nano DAP	297.33	282.67	290.00
T_8	T_{12} + Seed Treatment @ 5 ml/kg seed + Foliar Spray @ 0.2% at 25-30 DAG with Nano DAP	296.33	283.00	289.67
T_9	50% NP through DAP (NPK 60:30:40 kg ha-1) + Foliar Spray @ 0.4% at 25-30 DAG with Nano DAP	291.33	278.00	284.67
T_{10}	50% NP through DAP (NPK 60:30:40 kg ha-1) + Seed Treatment @ 5 ml/kg seed + Foliar Spray @ 0.4% at 25-30 DAG with Nano DAP	292.33	279.00	285.67
T_{11}	Absolute Control (N0: P0: K0 kg ha^{-1})	263.67	255.33	259.50
T_{12}	75% NP through DAP (NPK 90:45:40 kg ha^{-1})	293.00	280.00	286.50
	C.D. (0.05)	4.98	7.17	6.02
	C.V.%	1.03	1.97	1.27

Table 3: Effect of application of Nano-DAP fertilizer on spike length (cm) and spike weight (g) of wheat during 2021-22 and 2022-23.

Treatment details		Spike length (cm)			Spike weight (g)		
		2021	2022	Mean	2021	2022	Mean
T_1	0% NP (Control); N0: P0: K40 kg ha^{-1}	8.10	8.08	8.09	1.22	1.13	1.18
T_2	100% NP through DAP (NPK 120: 60: 40 kg/ha)	8.66	8.51	8.59	1.69	1.60	1.65
T_3	T_1 + Seed Treatment @ 5 ml/kg seed with Nano DAP	8.21	8.11	8.16	1.26	1.17	1.21
T_4	T_1 + Seed Treatment @ 10 ml/kg seed with Nano DAP	8.22	8.13	8.18	1.36	1.27	1.31
T_5	T_1 + Foliar Spray @ 0.6% at 25-30 DAG with Nano DAP	8.18	8.10	8.14	1.29	1.20	1.25
T_6	T_1 + Seed Treatment @ 5 ml/kg seed + Foliar Spray @ 0.6% at 25-30 DAG with Nano DAP	8.21	8.12	8.17	1.32	1.23	1.28
T_7	T_{12} + Foliar Spray @ 0.2% at 25-30 DAG with Nano DAP	8.55	8.46	8.51	1.52	1.43	1.48
T_8	T_{12} + Seed Treatment @ 5 ml/kg seed + Foliar Spray @ 0.2% at 25-30 DAG with Nano DAP	8.61	8.50	8.55	1.56	1.47	1.51
T_9	50% NP through DAP (NPK 60:30:40 kg ha^{-1}) + Foliar Spray @ 0.4% at 25-30 DAG with Nano DAP	8.42	8.37	8.40	1.39	1.30	1.35
T_{10}	50% NP through DAP (NPK 60:30:40 kg ha^{-1}) + Seed Treatment @ 5 ml/kg seed + Foliar Spray @ 0.4% at 25-30 DAG with Nano DAP	8.43	8.38	8.41	1.42	1.33	1.38
T_{11}	Absolute Control (N0: P0: K0 kg ha^{-1})	8.15	8.00	8.07	1.12	1.13	1.12
T_{12}	75% NP through DAP (NPK 90:45:40 kg ha^{-1})	8.53	8.43	8.48	1.49	1.40	1.45
	C.D. (0.05)	N.S.	N.S.	NS	N.S.	N.S.	NS
	C.V.%	5.14	3.12	2.6	7.31	7.82	7.55

Table 4: Effect of different combinations of Nano-DAP fertilizer on test weight of wheat (g) during 2021 and 2022

Treatment details		Test weight (g)		
		2021-22	2022-23	Mean
T_1	0% NP (Control); N0: P0: K40 kg ha^{-1}	35.43	34.21	34.82
T_2	100% NP through DAP (NPK 120: 60: 40 kg ha^{-1})	40.06	38.72	39.39
T_3	T_1 + Seed Treatment @ 5 ml/kg seed with Nano DAP	36.62	34.49	35.55
T_4	T_1 + Seed Treatment @ 10 ml/kg seed with Nano DAP	37.97	36.07	37.02
T_5	T_1 + Foliar Spray @ 0.6% at 25-30 DAG with Nano DAP	37.01	34.82	35.92
T_6	T_1 + Seed Treatment @ 5 ml/kg seed + Foliar Spray @ 0.6% at 25-30 DAG with Nano DAP	37.52	35.85	36.68
T_7	T_{12} + Foliar Spray @ 0.2% at 25-30 DAG with Nano DAP	39.29	38.35	38.82
T_8	T_{12} + Seed Treatment @ 5 ml/kg seed + Foliar Spray @ 0.2% at 25-30 DAG with Nano DAP	39.38	38.63	39.01
T_9	50% NP through DAP (NPK 60:30:40 kg ha-^{1}) + Foliar Spray @ 0.4% at 25-30 DAG with Nano DAP	38.16	36.98	37.57
T_{10}	50% NP through DAP (NPK 60:30:40 kg ha-^{1}) + Seed Treatment @ 5 ml/kg seed + Foliar Spray @ 0.4% at 25-30 DAG with Nano DAP	38.67	37.16	37.92
T_{11}	Absolute Control (N0: P0: K0 kg ha^{-1})	35.11	34.10	34.61
T_{12}	75% NP through DAP (NPK 90:45:40 kg ha-^{1})	38.91	37.84	38.38
	C.D. (0.05)	N.S.	N.S.	NS
	C.V.%	4.91	7.09	3.99

Table 5: Effect of different combinations of Nano-DAP fertilizer on grain and straw yield (q/ha) of wheat during 2021 and 2022

Treatment details		Grain yield (q/ha)		Straw yield (q/ha)	
		2021-22	2022-23	2021-22	2022-23
T_1	0% NP (Control); N0: P0: K40 kg ha^{-1}	12.80ef	12.39gh	16.82f	15.50e
T_2	100% NP through DAP (NPK 120: 60: 40 kg ha^{-1})	31.65a	30.33ab	36.12a	37.68a
T_3	T_1 + Seed Treatment @ 5 ml/kg seed with Nano DAP	15.84de	15.31fg	19.37e	18.78d
T_4	T_1 + Seed Treatment @ 10 ml/kg seed with Nano DAP	17.59d	18.56e	20.64e	22.92c
T_5	T_1 + Foliar Spray @ 0.6% at 25-30 DAG with Nano DAP	16.53d	17.17ef	18.95e	21.34cd
T_6	T_1 + Seed Treatment @ 5 ml/kg seed + Foliar Spray @ 0.6% at 25-30 DAG with Nano DAP	17.12d	17.94ef	19.61e	22.27c
T_7	T_{12} + Foliar Spray @ 0.2% at 25-30 DAG with Nano DAP	28.30bc	28.61abc	33.48ab	36.08a
T_8	T_{12} + Seed Treatment @ 5 ml/kg seed + Foliar Spray @ 0.2% at 25-30 DAG with Nano DAP	29.80ab	30.92a	33.97a	38.34a
T_9	50% NP through DAP (NPK 60:30:40 kg ha^{-1}) + Foliar Spray @ 0.4% at 25-30 DAG with Nano DAP	25.04c	24.83e	27.40d	30.96b
T_{10}	50% NP through DAP (NPK 60:30:40 kg ha^{-1}) + Seed Treatment @ 5 ml/kg seed + Foliar Spray @ 0.4% at 25-30 DAG with Nano DAP	26.59c	25.14de	28.65cd	30.92b
T_{11}	Absolute Control (N0: P0: K0 kg ha^{-1})	12.31f	12.08h	15.32g	14.97e
T_{12}	75% NP through DAP (NPK 90:45:40 kg ha^{-1})	27.54bc	28.17bcd	31.25bc	35.18a
	C.D. (P = 0.05)	2.8	3.16	3.58	3.94
	C.V. (%)	7.60	8.55	8.41	8.6

Conclusion

In wheat treatment with 75% NP through DAP in combination of Nano-DAP gave at par results with treatment having application of 100% NP through DAP in plant height, ear heads per meter square, grain yield and straw yield. The results revealed that 25% of conventional application of DAP fertilizer can be saved by application through combination of nano DAP fertilizer with DAP in wheat.

Acknowledgments

This work is part of Ph.D. research work of Deepika Sahu. This work is supported by IGKV, Raipur. The corresponding author is thankful to Vice chancellor, head of the department of Soil Science and Agricultural Chemistry, for providing support during the course of the study.

References

1. Abdel-Aziz HMM, Hasaneen MNA, Omer AM. Impact of engineered nanomaterials either alone or loaded with NPK on growth and productivity of French bean plants: seed priming vs foliar application. South African Journal of Botany. 2019;125:102-108.
2. Adhikari T, Kundu S. Nano rock phosphate: a potential phosphatic fertilizer to crops. Agrochimica. 2017;61(1):13-27.
3. Al-Juthery HWA, Lahmod NR, Al-Taee RAHG. Intelligent nano-fertilizers: a new technology for improving nutrient use efficiency. International Scientific Agricultural Conference. 2018.
4. Alam MM, Ladha JK. Optimizing phosphorus fertilization in an intensive vegetable-rice cropping system. Biology and Fertility of Soils. 2004;40:277-283.
5. Alkahtani J, Elshikh MS, Alwahibi MS, Muhammad A, Khalid S. Phosphorus and zinc fertilization improve productivity and profitability of rice cultivars under rice-wheat system. Agronomy. 2020;10(8):1085.
6. Amanullah, Khalil SK, Jan A, Irfanullah M, Shah Z, *et al.* Phosphorus and zinc fertilization improve productivity and profitability of rice cultivars under rice-wheat system. Agronomy. 2020;10(8):1085.
7. Bakhtiar M, Afridi MZ, Munsif F, Arshad IUR, Rehman S, Khan S, *et al.* Dry matter partitioning and grain yield of wheat as affected by sources, methods and timing of nitrogen application. Pure and Applied Biology (PAB). 2017;6(4):1198-1215.
8. Chen H. Metal-based nanoparticles in agricultural systems: behaviour, transport, and interaction with plants. Chemical Speciation and Bioavailability. 2018;30(1):123-134.
9. Chauhan BS, Mahajan G, Sardana V, Timsina J, Jat ML. Productivity and sustainability of the rice-wheat

cropping system in the Indo-Gangetic Plains of the Indian subcontinent. Advances in Agronomy. 2012;115:315-369.
10. Deo HR, Chandrakar T, Srivastava LK, Nag NK, Singh DP, Thakur A. Effect of nano-DAP on yield, nutrient uptake and nutrient use efficiency by rice under Bastar plateau. The Pharma Innovation Journal. 2022;11:1463-1465.
11. Fageria NK, Knupp AM, Moraes MF. Phosphorus nutrition of lowland rice in tropical lowland soil. Communications in Soil Science and Plant Analysis. 2013;44(20):2932-2940.
12. Hardke JT. Arkansas Rice Production Handbook. Little Rock (AR): Cooperative Extension Service, University of Arkansas; 2013.
13. Hasanuzzaman M, Nahar K. Tiller dynamics of three irrigated rice varieties under varying phosphorus levels. American-Eurasian Journal of Agronomy. 2009;2(2):89-94.
14. Jassim RAH, Kadom HN, Ghanim B. Impact of levels and time of foliar application of nano-fertilizer (Super Micro Plus) on growth and yield components of rice (*Oryza sativa* L.). Plant Archives. 2019;19(1):1434-1438.
15. Kalwani M, Chakdar H, Srivastava A, Pabby S, Shukla P. Effects of nanofertilizers on soil and plant-associated microbial communities: emerging trends and perspectives. Chemosphere. 2022;287:132107.
16. Kiran K, Samal KC. Nano urea liquid-a boon for Indian farmers and mother earth. Biotica Research Today. 2021;3(6):511-514.
17. Kumar R, Singh RK, Panda A, Singh SK. Nano urea: an efficient tool for precision agriculture and sustainability. Vigyan Varta. 2021;2(9):72-74.
18. Laheri S, Hussain SA, Parmeshwari YS, Sharma SHK. Grain yield and nutrient uptake of rice as influenced by the nano forms of nitrogen and zinc. International Journal of Environment and Climate Change. 2021;11:1-10.
19. Meena RS, Neupane MP, Singh SK. Effect of phosphorus levels and bio-organic sources on growth and yield of rice (*Oryza sativa* L.). International Journal of Agricultural Sciences. 2015;11(2):286-289.
20. Sorour FA, Metwally TF, El-Degwy IS, Eleisawy EM, Zidan AA. Effects of nano phosphatic fertilizer application on the productivity of some Egyptian rice varieties (*Oryza sativa* L.). Applied Ecology and Environmental Research. 2020;18(6):7673-7684.
21. Timsina J, Connor DJ. Productivity and management of rice-wheat cropping systems: issues and challenges. Field Crops Research. 2001;69(2):93-132.
22. Villagómez EM, Trejo-Téllez LI, Gómez-Merino FC, Sandoval-Villa M, Sánchez-García P, Aguilar-Méndez MA. Nano phosphorus fertilizer stimulates growth and photosynthetic activity and improves P status in rice. Journal of Nanomaterials. 2019;2019:1-11.
23. Wiedenhoeft AC. Plant Nutrition. Chelsea House Press; 2006. p. 144.
24. Yang G, Zhang W, Guo Q, *et al.* Effects of nitrogen and phosphorus regulation on plant type, population ecology and sheath blight of hybrid rice. Plants. 2022;11(17):2306.
25. Ye T, Wu X, Duan H, *et al.* Nitrogen, phosphorus, and potassium fertilization affects the flowering time of rice (*Oryza sativa* L.). Global Ecology and Conservation. 2019;20:e00753.