Impact of different nano-fertilizers on agronomic traits of wheat under Jammu subtropics

Abstract

NPK fertilizers are vital for wheat cultivation, but their excessive and improper use can harm both human health and the environment. Thus, exploring alternatives like nano fertilizers, which provide a slow and controlled release of nutrients, is essential. Keeping this in view, an experiment was conducted at the Research Farm of Division of Soil Science and Agricultural Chemistry, Chatha, Jammu, Jammu and Kashmir during the *rabi* season of 2021-2022 and 2022-2023 to study the effects of nano NPK fertilizers on wheat cultivar 'HD-3086'. The experiment followed a Randomized Block Design with 12 treatments and 3 replications across 36 plots. The treatments ranged from control (no fertilizers) to varying levels of recommended doses of Fertilizers (RDF) of NPK *viz.* 100%, 75%, 50%, combined with different numbers of foliar sprays of nano-NPK at tillering, jointing, and booting stages. The significantly higher results with respect to growth parameters and yield were recorded under treatment T_8 (100% RDF [NPK] + 3 foliar sprays of nano-NPK at tillering, jointing, and booting stages) which was at par with treatment T_5 (100% RDF [NPK] + 2 foliar sprays of nano-NPK at tillering, and booting stages) but showed no significant variation in harvest index. In contrast, the control treatment, which received no fertilizer, exhibited the poorest growth and yield performance at harvest.

Key words: Wheat, Nano N, P and K fertilizers, RDF and Yield

Introduction

Wheat (*Triticum aestivum* L.) is the second most important cereal crop in India after rice, contributing around 35% of the country's total food grain production. China, India, U.S.A., Russia, France, Canada, Germany, Turkey, Australia and Ukraine are leading wheat producing countries. In India, wheat stands in second position under area and production, but first in productivity amongst all the cereals with acreage, production and productivity of 31.80 million hectares, 112.90 million tonnes and 3528 kg/ha, respectively (Anonymous, 2024). In Jammu and Kashmir, wheat is a significant crop

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cultivated during the *rabi* season and covers an area of approximately 292 thousand hectares, with an annual production of 584 thousand metric tonnes. However, the average wheat productivity in Jammu and Kashmir is lower compared to the national average, standing at around 2.06 tonnes per hectare (Anonymous, 2023).

Wheat has played a crucial role in the success of the Green Revolution, helping India transition from a food-scarce nation to one that is self-sufficient. The rise in crop productivity is largely dependent on the use of fertilizers, which provide essential nutrients to the plants. Macronutrients such as nitrogen (N), phosphorus (P), and potassium (K) are vital for crop growth, with phosphorus being a key component of ADP and ATP, necessary for energy transformation and storage. It also aids in the assimilation of photosynthates into metabolites, facilitating CO□ assimilation. Potassium, the most abundant cation in plants, is critical for enzyme activation, protein synthesis, photosynthesis, osmoregulation, stomatal movement, energy transfer, phloem transport, cation-anion balance, and stress resistance (Gul *et al*., 2015). These macronutrients are supplemented through conventional fertilizers but the uptake and use efficiency of nutrients through conventional fertilizers is very less, causing soil and ground water pollution. These conventional synthetic fertilizers have short-term benefits but cause long-term problems when applied in bulk as they leave residues which are toxic in nature and contributes heavy load to soil. Moreover, the increasing cost of fertilizers is also a burden for the farmer. However, the use of Nano-fertilizers instead of conventional synthetic fertilizers is a way to release nutrients into soil in controlled and conditional way thus, reducing the loss of nutrients (Arif *et al.*, 2016). These are also safer than the conventional inorganic fertilizer from the angle of soil and environmental degradation. Nano-fertilizers have large surface area and particle size less than the pore size of root and leaves of the plant which can increase penetration into the plant from applied surface and improve uptake and nutrient use efficiency. Nano-fertilizer is required in less quantity, so it reduces the cost of fertilizers and also reduces the chemical load of fertilizers in the soil. Nano-fertilizer applications to the soil or in foliar form in small quantities increased growth and yield of crops compared to bulky fertilizers of the same elements. The fertilizer use efficiency was better due to penetration ability and translocation within the plant parts (Ghorbanpour *et al.*, 2020).

Foliar application is the technique of feeding plants by spraying liquid fertilizers directly to the leaves (Nasiri and Najafi, 2015). Nano-fertilizers have an important role in the physiological and

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biochemical processes of crops by increasing the availability of nutrients, which help in enhancing metabolic processes and promoting meristematic activities causing higher apical growth and photosynthetic area (DeRosa *et al.* 2010). Nano-fertilizers, developed using nanotechnology, are smaller in size with larger surface areas, which increases absorption capacity and allows for controlled-release to targeted site. The combined use of traditional fertilizers and nano-fertilizers can maintain a balanced nutrient supply throughout the various growth stages of wheat, reduce the need for chemical fertilizers, and create a better environment for nutrient absorption. This approach aims to improve nutrient use efficiency and boost wheat yield. Keeping these points under consideration, a study will be conducted to study the combined effect of fertilizers applied through commercial fertilizers and foliar application of different Nano fertilizers of nitrogen, phosphorus and potassium on wheat crop growth and yield.

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Materials and Methods

A field experiment was carried out during *rabi* season of the 2021-2022 and 2022-2023 at Research Farm of Division of Soil Science and Agricultural Chemistry, Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Chatha. The site is geographically situated at 32° 40' N latitude and 74° 58' E longitude, with an elevation of 332 meters above sea level in the Shiwalik foothills of the Northwestern Himalayas. The subtropical climate of the experimental site is typified by hot, dry early summers, hot, humid monsoons, and cold, dry winters. The yearly average rainfall is between 1050 and 1115 mm, with 70% of the precipitation occurring between June and September and the remaining 30% dropping in sporadic winter showers brought on by western disturbances from December to March. The overall amount of rainfall and its distribution do, however, differ greatly. The site's soil is a clay loam and a somewhat alkaline composition.

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The experiment was laid out in the randomized-block design with twelve treatments and three replications. Urea, DAP, MOP were used as chemical sources of fertilizers and for nano-fertilizer treatments, Nano urea, Nano DAP and Nano Potash in liquid forms were used. The experiment consisted of 12 treatments *viz*. T_1: Control (No fertilizer), T_2: 100% RDF (recommended dose of fertilizers) of NPK through soil application, T_3: 75% RDF of NPK as soil application, T_4: 50% RDF(NPK) through soil application, T_5: 100% RDF of NPK as soil application + 2 Foliar sprays of

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Nano-NPK at tillering and jointing stage, T_6: 75 % RDF of NPK as soil application + 2 Foliar sprays of Nano – NPK at tillering and jointing stage, T_7: 50% RDF of NPK as soil application + 2 Foliar sprays of Nano – NPK at tillering and jointing stage, T_8: 100% RDF of NPK as soil application + 3 Foliar sprays of Nano – NPK at tillering, jointing stage and booting stage, T_9: 75 % RDF of NPK as soil application + 2 Foliar sprays of Nano – NPK at tillering and jointing stage, T_{10}: 50% RDF of NPK as soil application + 2 Foliar sprays of Nano – NPK at tillering and jointing stage, T_{11}: Control + 2 Foliar sprays of Nano- NPK at tillering and jointing stage,T_{12}: control + 3 Foliar sprays of Nano-NPK at tillering, jointing and booting stage. The wheat variety HD -3086 was sown in the month of November during both years. Recommended dose of NPK fertilizers i.e 100, 50 and 20 kg ha^{-1} was applied and foliar spray of Nano fertilizers (NPK) were applied as per the treatments.

Five randomly chosen plants from each plot were used to assess the outcomes of treatment, and the average of those plants has been recorded as the last observation at the harvest stage. Plant samples for dry matter accumulation were taken at the harvesting stage. After harvesting, the plants were clipped close to soil surface from each plot. The samples were sundried for 3-4 days and then shifted in the oven to dry at a temperature of 65 C till a constant weight was achieved and dry matter accumulation was recorded and expressed as dry weight in g m^{-2}. From the individual plot, net plot was harvested, sun dried for 3-4 days and was subsequently threshed and cleaned. The grains thus obtained, were weighted and expressed in kg ha^{-1}. The straw yield per net plot was recorded by subtracting the total grain weight from the total biomass from the perspective treatment and the straw yield obtained was expressed in kg ha^{-1}. Harvest index was calculated by dividing the economic yield to the biological yield as per the formula given by Nichiporovich (1967).

$$\text{Harvest index (per cent)} = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

After the spikelet's grew mature and the plants dried, harvesting was done. Plot-by-plot, the crop was manually threshed, and grain and straw were gathered independently.

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Results and Discussion

The treatments that combined the recommended fertilizer dosage with foliar Nano NPK spray had a significant effect on the eventual plant height, dry matter accumulation, grain yield, straw yield, and harvest index of the wheat crop in both the years of experimentation. The findings along with relevant discussions, are summarized under the following heads.

Plant height (cm)

The data on plant height at harvesting in wheat crop is presented in table 1 which showed that plant height varied between 73.60 and 158.94 cm, 77.28 and 166.89 cm (*rabi* 2021-22 and 2022-23). The significantly highest plant height was obtained in treatment T_8 i.e., 100% RDF + 3 Foliar sprays of Nano NPK at three different stages of plant growth viz. tillering, jointing and booting stage (158.94 cm and 166.89 cm) than all other treatments except treatment T_5 (100% RDF + 2 Foliar sprays of nano -NPK at tillering & jointing) (157.35 cm and 165.21cm) which was at par with treatment T_8 and the lowest plant height was recorded in treatment T_1(control) (73.60 cm and 77.28 cm). The notable increase in plant height at higher levels of RDF combined with nano fertilizers is likely due to enhanced cell division and elongation in the meristematic regions of the plants. This effect is a result of the synergistic role of nano fertilizers and conventional nutrients in boosting the plant growth of wheat. N being essential element for amino acids, proteins, vitamins, hormones, and enzymes, significantly contributes to cell division and enlargement, leading to taller plants. Even at lower application rates, the combination of nano fertilizers with traditional fertilizers has been observed to increase wheat plant height. Similar effects on plant height with the use of NPK and nano nutrients were reported by Mehta (2017) and Singh *et al.* (2022), and nano urea by Rawate *et al.* (2022).

Dry matter accumulation (g/m^2)

At harvesting, the highest dry matter was accumulated (g/m^2) in treatment T_8 (1342.74 g/m^2 and 1392.69 g/m^2) receiving 100% RDF of NPK + 3 Foliar sprays of Nano NPK at three different stages of plant growth (tillering, jointing and booting stage), being significantly superior over other treatments however was at par with the treatment T_5 100% RDF of NPK + 2 Foliar sprays of nano -NPK at tillering & jointing (1329.26 and 1378.70 g/m^2). The significant increase in dry matter

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accumulation can be attributed to the beneficial effects of nano fertilizers on plant height, tiller production, and leaf area index. These factors contribute to an enhanced photosynthetic rate and increased food production in the leaves. The larger leaf area likely improved the utilization of solar radiation and nutrient absorption, resulting in greater biomass and nutrient uptake. This cumulative growth effect, reflected in higher dry matter accumulation, is linked to increased crop growth rates. The slow and sustained nutrient release from nano fertilizers, especially in combination with RDF, also contributed to improved growth parameters and synchronization of nitrogen supply, ultimately boosting crop growth and biomass production. These findings align with studies by Singh *et al*. (2022), Dhoke *et al*. (2013) and Benzon *et al*. (2015) who observed similar improvements in wheat growth and dry matter accumulation with nano fertilizers.

Grain Yield (kg ha^{-1})

Treatment T_8 (100% RDF (NPK) + 3 Foliar sprays of Nano fertilizers at three stages *viz*. tillering, jointing and booting stage) recorded significantly higher grain yield (kg ha^{-1}), which was statistically at par with the application of 100% RDF (NPK) + 2 Foliar sprays of Nano fertilizers at two stages *viz*. tillering and jointing stage. These treatments registered 4541.21 and 4677.44 kg ha^{-1} respectively, Significantly, lowest grain yield was observed in T_1 (Control) (2102.85 and 2165.94 kg ha^{-1}). Foliar application of nano NPK fertilizers significantly enhances nutrient absorption leading to improve plant growth, higher photosynthetic rates, and better metabolic processes. The slow and sustained release of these nano nutrients optimizes their interception and utilization, ultimately boosting yield attributes, straw yield, and overall crop productivity. These results align with studies by Poudel *et al*. (2023) and Saraiva *et al*. (2022), which demonstrate similar benefits in wheat crop. Moreover, the synergistic effect of nano fertilizers with recommended doses of fertilizers (RDF) enhances nutrient use efficiency, hormone regulation, and carbon translocation, contributing to improved yield components and grain formation, as noted by Abdel-Aziz *et al*. (2018) and Sahu *et al*. (2023).

Straw yield (kg ha^{-1})

Treatment T_8 (100 % RDF with 3 foliar sprays of Nano NPK at tillering, jointing and booting stage) (9082.40 and 9536.51 kg ha^{-1}) had the higher straw yield (kg ha^{-1}) which was significantly superior over the other treatments and the lower straw yield was recorded under control T_1(3247.70

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and 3410.13 kg ha^{-1}). The increased straw yield observed with nano fertilizers can be attributed to its quick absorption and efficient translocation, resulting in higher dry matter accumulation, as supported by findings from Tarafdar *et al.* (2014) and Kumar *et al.* (2020).

Harvest Index (%)

Numerically highest harvest index was recorded under treatment T_8 *i.e.,* 100 % RDF + 3 Foliar sprays of Nano NPK at 3 stages *i.e.,* tillering, jointing and booting stage, which was followed by Treatment T_5 (100% RDF + 2 Foliar sprays of Nano NPK at tillering and jointing stage). However, foliar application of Nano NPK at 3 stages of plant growth failed to show any significant effect on harvest index of wheat.

Conclusion:

Based on the two years of experimentation, it can be concluded that applying 100% RDF of NPK + 2 Foliar sprays of nano NPK at two growth stages of plant *i.e.,* tillering and jointing significantly enhances wheat productivity over other treatments but remained at par with 100% RDF of NPK + 3 Foliar sprays of nano NPK at three growth stages of plant growth *viz i.e.,* tillering, jointing and booting. The findings emphasize that foliar application of nano fertilizers effectively delivers essential nutrients, enhancing crop yield while ensuring environmental safety and efficient nutrient use. These results highlight the potential of nano fertilizers in sustainable agricultural practices.

Reference

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Fig 1: Effect of nano NPK fertilizers on plant height (cm) and dry matter accumulation (g/m^2) of wheat crop

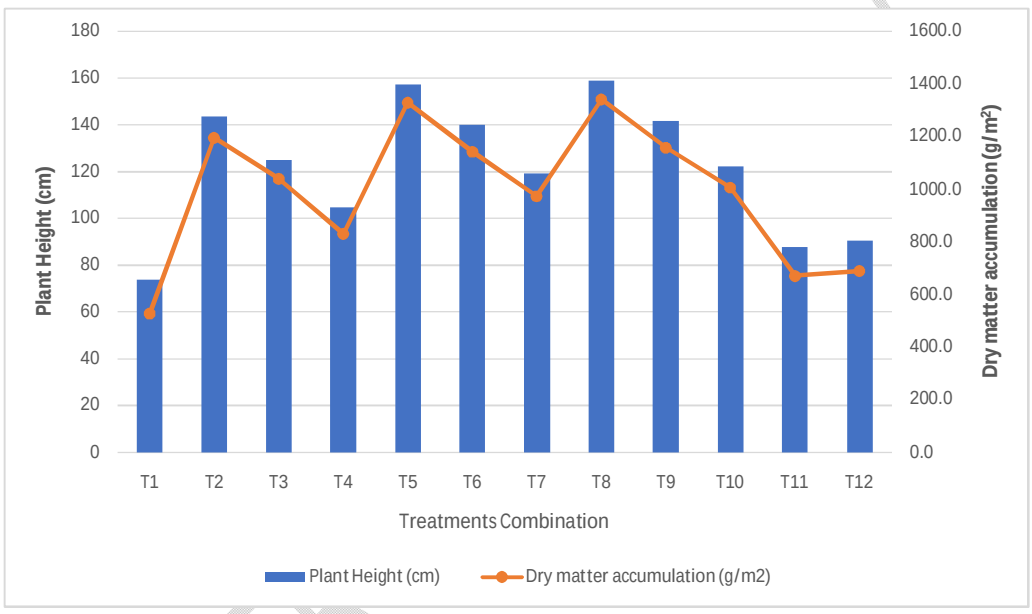

Table 1: Effect of nano NPK fertilizers on plant height (cm) and dry matter accumulation (g/m^2) of wheat crop at harvesting

S. No.	Treatments	Plant Height (cm)		Dry matter accumulation (g/m^2)	
		2021-22	2022-23	2021-22	2022-23
T_1	Control (No fertilizer)	73.60	77.28	527.35	546.34
T_2	100% RDF (NPK)	143.55	150.72	1196.25	1240.64
T_3	75% RDF	124.93	131.18	1038.97	1077.51
T_4	50% RDF	104.79	110.03	830.61	861.14
T_5	100%RDF + 2 Foliar sprays of nano -NPK at tillering & jointing	157.35	165.21	1329.26	1378.70
T_6	75% RDF + 2 foliar sprays of nano- NPK at tillering and jointing stage	139.90	146.89	1142.44	1184.67
T_7	50% RDF + 2 foliar sprays of nano-NPK at tillering stage & jointing stage	119.17	125.13	973.90	1009.91
T_8	100% RDF + 3 foliar sprays of nano-NPK at tillering stage, jointing and booting stage	158.94	166.89	1342.74	1392.69
T_9	75% RDF+ 3 foliar sprays of nano NPK at tillering stage, jointing and booting stage	141.76	148.85	1158.15	1200.96
T_{10}	50% RDF + 3 foliar sprays of nano NPK at tillering stage, jointing and booting stage	122.25	128.36	1006.47	1043.73
T_{11}	Control+ 2 foliar sprays of nano NPK at tillering and jointing stage	87.80	92.19	670.46	694.93
T_{12}	Control + 3 foliar sprays of nano NPK at tillering, jointing and booting stage	90.71	95.24	690.08	715.24

Sem ±	4.67	4.91	32.54	33.88
CD (5%)	13.79	14.48	96.01	99.96

Table 2: Effect of nano NPK fertilizers on grain yield (kg/ha) and harvest index (%) of wheat crop at harvesting

S.No.	Treatments	Grain yield (kg/ha)		Harvest index (%)	
		2021-22	2022-23	2021-22	2022-23
T_1	Control (No Fertilizer)	2102.85	2165.94	39.32	38.86
T_2	100% RDF (NPK)	4101.33	4224.37	33.90	33.47
T_3	75% RDF	3569.39	3676.48	33.87	33.44
T_4	50% RDF	2994.03	3083.85	35.57	35.13
T_5	100%RDF + 2 Foliar sprays of nano - NPK at tillering & jointing	4495.62	4630.49	33.30	32.87
T_6	75% RDF + 2 foliar sprays of nano-NPK at tillering and jointing stage	3997.11	4117.02	34.47	34.04
T_7	50% RDF + 2 foliar sprays of nano-NPK at tillering stage & jointing stage	3404.88	3507.03	34.46	34.03
T_8	100% RDF + 3 foliar sprays of nano-NPK at tillering stage, jointing and booting stage	4541.21	4677.44	33.47	33.05
T_9	75% RDF+ 3 foliar sprays of nano NPK at tillering stage, jointing and booting stage	4050.22	4171.73	34.51	34.07
T_{10}	50% RDF + 3 foliar sprays of nano NPK at tillering stage, jointing and booting stage	3492.79	3597.58	34.29	33.85

T_{11}	Control+ 2 foliar sprays of nano NPK at tillering and jointing stage	2508.64	2583.90	36.88	36.44
T_{12}	Control + 3 foliar sprays of nano NPK at tillering, jointing and booting stage	2591.65	2669.40	36.96	36.51
Sem ±		2102.85	2165.94	1.37	1.36
CD (5%)		4101.33	4224.37	NS	NS