Performance of Wheat (*Triticum aestivum* L.) influenced by the application of Nano-fertilizers

Abstract

An experiment into the "Performance of wheat (*Triticum aestivum* L.) on the application of nano-fertilizers" was conducted on well-drained sandy soil in response to concerns about food and nutritional security as well as second-generation post-green revolution problems, such as increasing input use with declining efficiency trends, deteriorating soil health, depleting water resources, pollution and narrowing farmer profits. On the wheat variety, DBW187 in RBD with three replications, 12 treatments containing control, basal administrations of the required 100% NPK (150:60:40), 75% NPK (112.5:45:30), and nano N and nano P in various combinations were tried. The study's findings showed that wheat sprayed with 75% NPK + Nano N and Nano P at 30 and 45 days of growth experienced significantly better growth as evidenced by taller plants (91.23 cm), more tillers per square metre (322.5), higher LAI (0.83), and higher dry matter accumulation per square metre (1532.7), all of which were measured at harvest.

Key~~-~~words: Dry matter, nano nitrogen, nano phosphorus, tiller

Introduction

In t~~T~~he world,~~'s~~ 40 per cent of people eat wheat (Triticum aestivum L.), which is also the second-most significant cereal after rice. For more than 4.5 billion people in 94 countries, wheat provides 20% of the protein and 21% of the food calories. With an output of 763.9 million metric tonnes and an average productivity of 3.53 metric tonnes per hectare, the world's wheat crop covers 216.9 million hectares **(USDA, 2020)**. With an area of 31.31 million ha and a production of 109.6 million metric tonnes with an average productivity of 3.52 metric tonnes per hectare **(USDA report, 2019)**, wheat also plays a significant role in food and nutritional security in India **(Tandon, 2000)**. Wheat will probably continue to play a significant role in securing global food security. With a 9.85 million ha area and a production of 35.50 million tonnes in 2020–21, Uttar Pradesh is the main wheat-growing state in India **(Khan et al., 2023)**. However, the state's wheat productivity is much lower than that of Punjab (4.3 tonnes/ha) and Haryana (4 tonnes/ha), which can be attributed to late sowing following the harvest of sugarcane and long-lasting rice varieties, poor seed replacement rates, a lack of high-quality seed, uneven fertilisation, haphazard water management, poor mechanisation, etc. Wheat is delayed from being sown in western Uttar Pradesh till the end of December and occasionally even into the first week of January, severely reducing yield. Farmers typically try to remedy delayed planting installed maturity under the impact of high temperatures by applying excessive amounts of nutrients, particularly nitrogen, while ignoring yield physiology in limited conditions. The importance of fertiliser recommendations based on soil test results, residual effects, and yield targets has increased in light of rising fertiliser prices and the environmental effects of unbalanced fertiliser use. When constructing and analyzing diverse crop production systems, low nutrient use efficiency (NUE) is a major consideration. Fertiliser, soil, and water management can have a significant impact on it in order to give the crop the economically optimal nourishment necessary to maximise production and reduce nutrient losses from the field **(Agrawal et al., 2014)**. Inorganic fertiliser has been used indiscriminately over the past 50 years, leading to widespread micronutrient deficiencies and a decline in the quality and output of agricultural products. Due to the ongoing global energy crisis and the rising cost of chemical fertiliser, using nano fertiliser as a source of plant nutrients is becoming more and more important. In this endeavour, a good balance of inorganic and nano fertilisers is crucial for maintaining soil health as well as enhancing productivity. For growth and productivity, wheat, a significant cereal crop, needs a strong supply of minerals, particularly nitrogen and phosphorus. ~~Application~~ The application of nano fertiliser improves soil fertility and reduces soil pollution. Application of nanomaterials either separately or in conjunction with inorganic fertilisers assisted in proper nutrient uptake and fertility maintenance of the soil. According to **(Hussain et al., 2002)**, the application of nano fertiliser boosted the effectiveness of chemical fertilisers. It is believed that regular use of chemical fertilisers is a major factor in the worsening of soil health and water contamination. ~~Use~~ The use of both mineral and nano fertilisers must be balanced if soil and crops are to remain productive and sustainable. In such a situation, there is a pressing need to look at alternative sources that can complement or replace the usage of expensive inputs like chemical fertiliser while simultaneously protecting the ecology. A useful addition that could take the place of chemical fertilisers is nano fertiliser. Along with improving the quality of the produce, it promotes plant growth and might aid in the prevention of plant disease. Keeping the aforementioned information in mind, the current experiment was conducted to determine how the use of nano-fertilizers in combination with chemical fertilisers affected the performance of wheat (*Triticum aestivum* L.).

Materials and Methods

Experimental site: The Student's Instructional Farm of Chandra Shekhar Azad

University of Agriculture and Technology, Kanpur is geographically located at 26^{0} 29' 35''N latitudeand 80^{0} 18' 35'' E longitudes at an altitude of 125.9 meters above from mean sea level. It lies in the alluvial belt of the Ggangetic Pplain and is located in the central part of Uttar Pradesh. Treatments (12) comprised levels of NPK (100% and 75%) in combination withnano / /bio nano fertilizer (NPK&Zn). The experiment was laid out in a randomized block design with three replications. The wheat variety Karan Vandana (DBW 187) was taken. Statistical analysis was done with the help of window-based SPSS (Statistical Product and Service Solutions)) Version 10.0, SPSS, Chicago, IL. The SPSS techniquewas used for the analysis of variance to define the statistical significance of the treatment effect at a 5 % probability level. Further, F- test and the significance of difference between treatments wereas examined by critical difference (CD) as described by **Gomez and Gomez (1984).**

The treatments were designed in accordance to with the objectives of the study as follows:

S. No	**Treatments**	**Symbol**
1	Control	T_1
2	100 % NPK (150:60:40 kg ha^{-1})	T_2
3	75 % NPK (112.5: 45: 30 kg ha^{-1})	T_3
4	75 % NPK + Nano N spray at 30 DAS	T_4
5	75 % NPK + Nano N spray at 45 DAS	T_5
6	75 % NPK + Nano N spray at 30 and 45 DAS	T_6
7	75 % NPK + Nano P spray at 30 DAS	T_7
8	75 % NPK + Nano P spray at 45 DAS	T_8
9	75 % NPK + Nano P spray at 30 and 45 DAS	T_9
10	75 % NPK + Nano N and Nano P spray at 30 DAS	T_{10}
11	75 % NPK + Nano N and Nano P spray at 45 DAS	T_{11}
12	75 % NPK + Nano N and Nano P spray at 30 and 45 DAS	T_{12}

Result and Discussion

3.1 Population Studies

According to the findings in Table 1, wheat plant populations were higher in crops getting nutrients from outside sources than in controls for both years, regardless of the treatments. These effects weren't considerable, though. A closer look at the data revealed that the number of plants per m-2 ranged from 219.08 in a crop that received no nutrients to 283.67 in a field that received 100% NPK (150:60:40 kg ha-1) fertilization. This might be connected to the ability of nano fertilisers to supply nutrients for a longer period of time. This supports nutrient supply management, which positively affects plant growth **(Subramaniain and Sharmila, 2009)**.

Table. 1 Effect of nutrient management strategies on plant population at 20 DAS

Treatments	**Plant population (No m^{-2})**
	20 DAS
Control	219
100 % NPK (150:60:40 kg ha^{-1})	270
75 % NPK (112.5: 45: 30 kg ha^{-1})	255
75 % NPK + Nano N spray at 30 DAS	257
75 % NPK + Nano N spray at 45 DAS	256
75 % NPK + Nano N spray at 30 and 45 DAS	254
75 % NPK + Nano P spray at 30 DAS	254
75 % NPK + Nano P spray at 45 DAS	253
75 % NPK + Nano P spray at 30 and 45 DAS	258
75 % NPK + Nano N and Nano P spray at 30 DAS	259
75 % NPK + Nano N and Nano P spray at 45 DAS	256
75 % NPK + Nano N and Nano P spray at 30 and 45 DAS	254

SEm±	**1.8**
CD (P = 0.05)	**5.14**

4.2 Crop studies

4.2.1 Plant height

Plant height grew as crop age increased. The rate of increment was maximum between 60 and 90 DAS, as shown in Table 2 and Figure 1, up until harvest. According to the results, wheat plants grown in control plots were smaller than those grown in other nutrient management methods. With the use of 100% NPK (150:60:40 kg ha-1) nutrition management practise, wheat plants measured 16.2 cm taller at the 30-day stage, outperforming all other treatments. At the 60-day mark, a plant's maximum height (62.63 cm) was achieved with a 75% NPK + Nano N and Nano P spray. The DAS treatment significantly outperformed the other therapies at 30 and 45 DAS. The variation in plant height was comparable to the applications of 75% NPK + Nano N at 30 and 45 DAS and 75% NPK + Nano N and Nano P at 30 DAS. At all growth phases, ~~a~~ nearly the same tendency was seen. At all growth phases, the control plots produced shorter plants and significantly reduced plant height. According to **Benzon et al. (2015)**, nano-fertilizer increased plant height more than conventional fertilisers because it can either supply nutrients to the plant or help it transport or absorb nutrients that are already accessible. This results in improved crop growth. The findings of this study supported those of **Manikandan and Subramaian (2016)**, who found that the application of nano fertilizers significantly increased certain vegetative development features. Because nitrogen levels stimulate the production of auxins, which promote cell division and elongation of all vegetative plant cells, fertiliser components play a significant role in the increase in plant height. Because nitrogen is a necessary component to create the amino acid, it also directly affects plant height. Tryptophan It is the main constituent of indol acetic acid (IAA), the main hormone of the plant. According to **Hansch and Mendel (2009)**, phosphorus and nitrogen, both play significant roles in the molecular structure of vital biomolecules involved in respiration and photosynthesis, as well as in the synthesis of amino acids that are used to build proteins and coenzymes that are necessary for many enzymes to function. This healthy balance of nitrogen, phosphorus, and potassium promotes the growth of the plant.

4.2.2 Number of tillers m^{-2}

All stages of wheat growth were significantly impacted by nutrient management practises. As shown in Table 3 and Figure 2, fewer tillers were observed at 30 DAS, grew at 90 DAS, and then declined once again at 90 DAS till harvest. It is obvious that the adoption of various nutrient management strategies resulted in a considerable variation in the number of tillers per square metre at various stages of wheat.

Table 2 Effect of nutrient management strategies on plant height cm at various crop growth stages

Treatments	**Plant height (cm)**			
	30 DAS	**60 DAS**	**90 DAS**	**at harvest**
Control	8.87	40.53	60.9	65.93
100 % NPK (150:60:40 kg ha^{-1})	16.20	53.98	80.0	83.4
75 % NPK (112.5: 45: 30 kg ha^{-1})	13.70	48.60	70.2	72.48
75 % NPK + Nano N spray at 30 DAS	12.00	56.60	82.2	86.00
75 % NPK + Nano N spray at 45 DAS	13.20	55.00	80.0	84.27
75 % NPK + Nano N spray at 30 and 45 DAS	13.07	58.93	83.6	87.33
75 % NPK + Nano P spray at 30 DAS	11.93	53.40	79.7	83.63
75 % NPK + Nano P spray at 45 DAS	13.27	51.07	78.5	82.6
75 % NPK + Nano P spray at 30 and 45 DAS	12.77	55.40	80.8	84.90
75 % NPK + Nano N and Nano P spray at 30 DAS	13.87	58.87	84.9	89.00
75 % NPK + Nano N and Nano P spray at 45 DAS	12.53	57.47	83.9	88.93
75 % NPK + Nano N and Nano P spray at 30 and 45 DAS	12.87	59.11	88.8	91.23
SEm±	**0.5**	**1.0**	**2.5**	**0.56**
CD (P = 0.05)	**1.1**	**2.61**	**7.3**	**1.60**

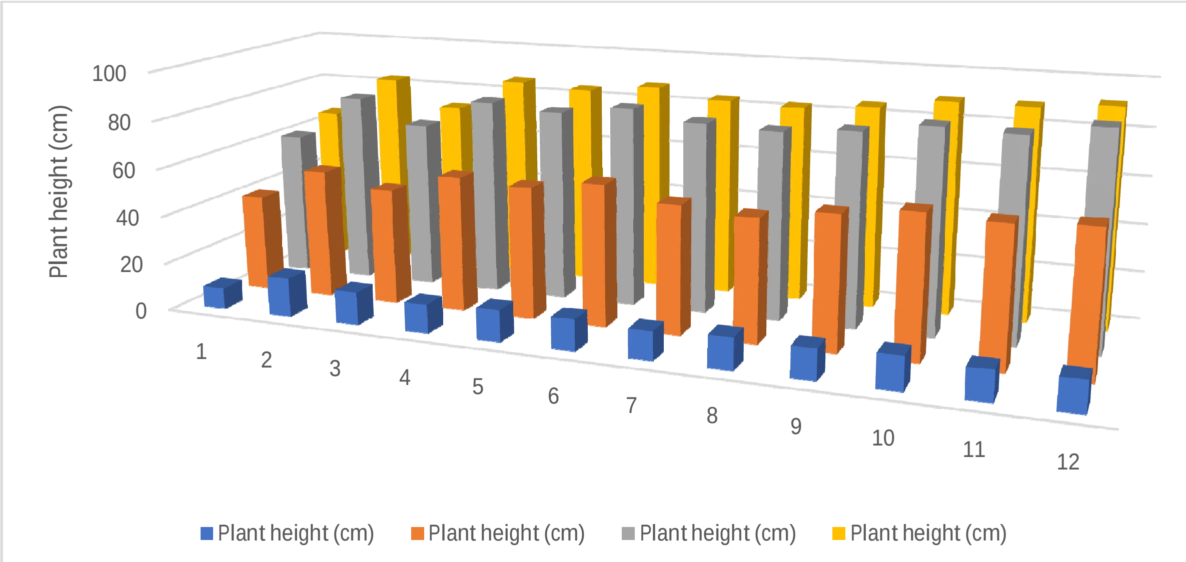


Fig.1 Effect of nutrient management strategies on plant height (cm) at different stages

The number of tillers m-2 varied from 74.5 to 101.5, 170.14 to 240.4, 299.45-326.1, and 297.5-322.5 at 30, 60, 90 DAS, and at harvest. The T-12 treatment with the integration of 75% NPK + Nano N and Nano P spray at 30 and 45 DAS except 30 DAS produced the greatest number of tillers at 30, 60, 90 DAS and harvest stage. There were noticeably more tillers produced as a result of the application of 75% NPK + Nano N and Nano P spray at 30 and 45 DAS at 60, 90, and harvest as compared to control and 100% NPK. Additionally, the number of tillers treated with T-6 did change significantly after the application of 75% NPK + Nano N spray at 30 and 45 DAS; this impact was statistically comparable to that of 75% NPK + Nano N and Nano P spray at 45 DAS. In comparison to the other four treatments, the control plot had the fewest tillers at all growth stages. The significant increase in the number of tillers per square metre was brought on by nano-fertilizers' induction of the increased activity of the chloroplast, rubisco, antioxidant enzyme system, and nitrate reductase, which may be a potential underlying mechanism for enhanced growth and an increase in the number of tillers **(Hong et al., 2005; Nekrasova et al., 2011)**.

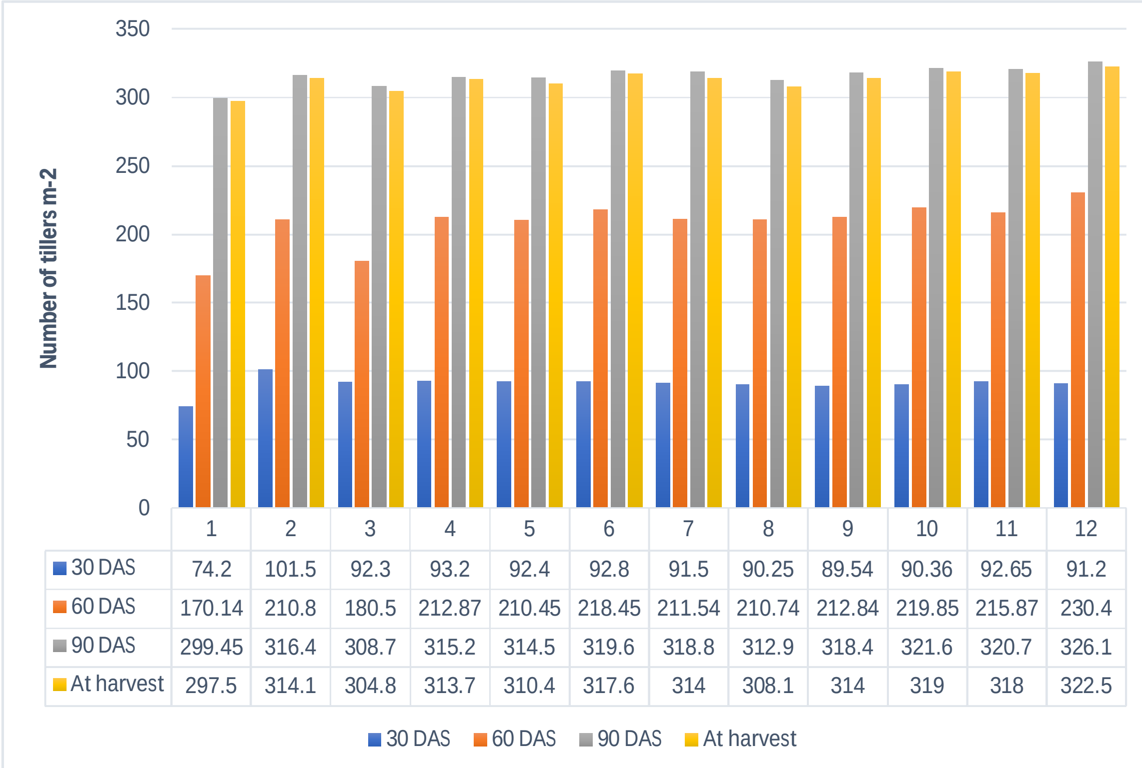
4.2.3 Dry matter accumulation

Generally speaking, dry matter buildup showed an upward tendency with increasing crop age and peaked during harvest (Table 5 & Figure 2). However, the pace of growth was modest for the first 30 days and peaked between 60 and the time of harvest. Regardless of the stages, crops getting no fertiliser nutrients had the noticeably lowest dry matter buildup. At later stages

Table 4 Effect of nutrient management strategies on the number of tillers m^{-2} at various crop growth stages

Treatments	Number of tillers m^{-2}			
	30 DAS	60 DAS	90 DAS	At harvest
Control	74.2	170.14	299.45	297.5
100 % NPK (150:60:40 kg ha-1)	101.5	210.8	316.4	314.1
75 % NPK (112.5: 45: 30 kg ha-1)	92.3	180.5	308.7	304.8
75 % NPK + Nano N spray at 30 DAS	93.2	212.87	315.2	313.7
75 % NPK + Nano N spray at 45 DAS	92.4	210.45	314.5	310.4
75 % NPK + Nano N spray at 30 and 45 DAS	92.8	218.45	319.6	317.6
75 % NPK + Nano P spray at 30 DAS	91.5	211.54	318.8	314.0
75 % NPK + Nano P spray at 45 DAS	90.25	210.74	312.9	308.1
75 % NPK + Nano P spray at 30 and 45 DAS	89.54	212.84	318.4	314.0
75 % NPK + Nano N and Nano P spray at 30 DAS	90.36	219.85	321.6	319.0
75 % NPK + Nano N and Nano P spray at 45 DAS	92.65	215.87	320.7	318.0
75 % NPK + Nano N and Nano P spray at 30 and 45 DAS	91.2	230.4	326.1	322.5
SEm±	**1.1**	**6.2**	**3.5**	**3.4**
CD (P = 0.05)	**3.3**	**17.77**	**10.5**	**9.8**

(60, 90 days and at harvest), application of either of nano nutrients or their simultaneous use with 75 % NPK increased plant dry matter significantly over 100% NPK**.** Further reducing NPK doses by 25% coupled with the application of nano nutrients reduced the number of tillers, however, it was not significant.



	1	2	3	4	5	6	7	8	9	10	11	12
30 DAS	74.2	101.5	92.3	93.2	92.4	92.8	91.5	90.25	89.54	90.36	92.65	91.2
60 DAS	170.14	210.8	180.5	212.87	210.45	218.45	211.54	210.74	212.84	219.85	215.87	230.4
90 DAS	299.45	316.4	308.7	315.2	314.5	319.6	318.8	312.9	318.4	321.6	320.7	326.1
At harvest	297.5	314.1	304.8	313.7	310.4	317.6	314	308.1	314	319	318	322.5

Fig.3 Effect of nutrient management strategies on number of tillers m^{-2} at different stages

In comparison to 100% and 75% of the suggested NPK and control, 100% NPK + Nano N + Bio Nano P + Bio Nano K + Bio Nano Zn application led to the largest accumulation of dry matter at all growth stages (apart from 30 DAS). When nano-N and nano-P were sprayed at 30 and 45 DAS in addition to 75% NPK, dry matter accumulation increased over control and 100% NPK by 43.05% and 12.69%, respectively, at harvest. Because nano-fertilizers are linked to higher plant height, more tillers per metre of row length, and a higher leaf area index, the considerable increase in dry matter accumulation may be the result of these factors. A higher leaf area index aids in improved nutrient utilisation and solar radiation absorption, both of which are necessary for greater accumulation of dry matter. Increased biomass production, chlorophyll production, photosynthetic surface area, and nutrient intake may be the causes of the rise in dry matter accumulation over time. Higher dry matter accumulation at regular intervals is thought to be the cause of the increased crop growth rate **(Kumar et al. 2020)**.

Treatments	**Dry matter accumulation (g m^{-2})**			
	30 DAS	**60 DAS**	**90 DAS**	**at harvest**
Control	28.6	210.4	712.1	872.1
100 % NPK (150:60:40 kg ha^{-1})	44.8	299.9	1170.1	1338.1
75 % NPK (112.5: 45: 30 kg ha^{-1})	35.3	222.6	925	1104
75 % NPK + Nano N spray at 30 DAS	34.6	305.1	1174.5	1356.5
75 % NPK + Nano N spray at 45 DAS	33.1	301.8	1124.9	1300.4
75 % NPK + Nano N spray at 30 and 45 DAS	33.45	308.5	1225	1397
75 % NPK + Nano P spray at 30 DAS	31.2	302.2	1192.6	1270.6
75 % NPK + Nano P spray at 45 DAS	33.5	300.2	1054.3	1234.8
75 % NPK + Nano P spray at 30 and 45 DAS	34.2	306.4	1140.58	1326.6
75 % NPK + Nano N and Nano P spray at 30 DAS	37.4	316.45	1276.5	1443
75 % NPK + Nano N and Nano P spray at 45 DAS	36.4	312..45	1170.55	1360.3
75 % NPK + Nano N and Nano P spray at 30 and 45 DAS	34.5	325.5	1342.2	1532.7
SEm±	**1.2**	**9.7**	**40.86**	**47.4**
CD (P = 0.05)	**3.6**	**17.9**	**117.3**	**136.08**

Table.5 Effect of nutrient management strategies on dry matter accumulation (g m^{-2}) at different stages

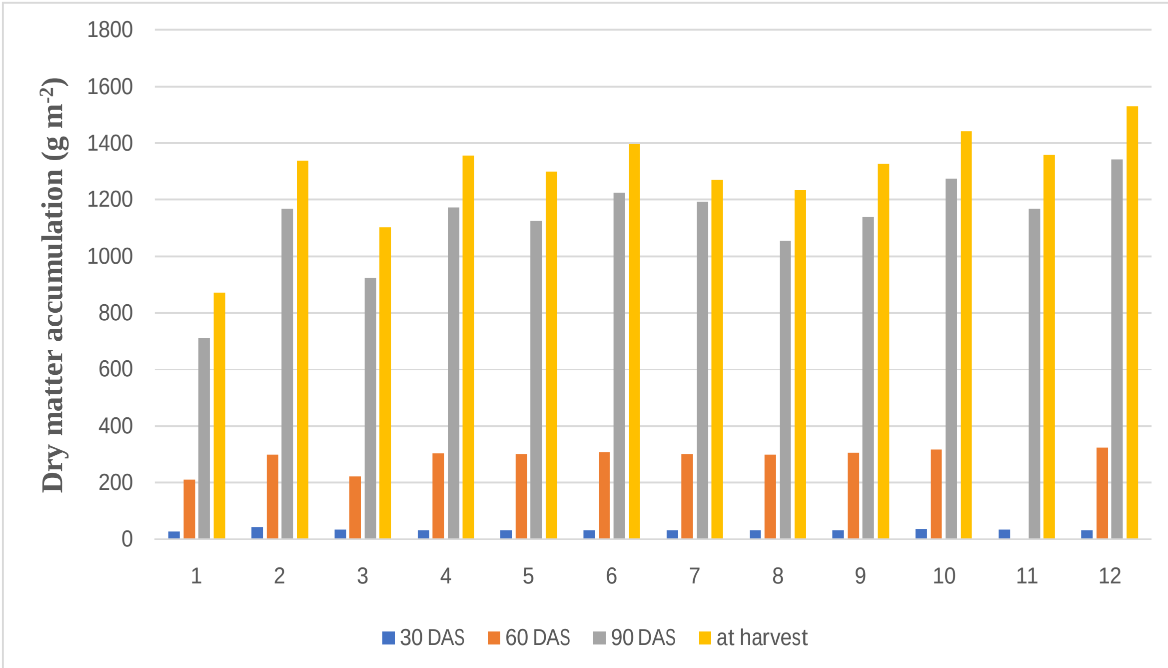


Fig.4 Effect of nutrient management strategies on dry matter accumulation (g m^{-2}) at different stages

4.2.4 Leaf area index

With crop age up to the 90-day stage, a gradual increase in leaf area index was seen (Table 6), which then sharply decreased after harvest. At all growth stages, with the exception of 30 DAS, nutrient application significantly enhanced leaf area index, regardless of doses and sources. A closer look at the data showed that using nano-sources considerably enhanced leaf area index over 100% NPK, regardless of nutrient or level of recommended NPK (75%). The crop treated with 75% NPK + Nano N and Nano P spray at 30 and 45 DAS at 90 DAS had the highest leaf area index, greatly outperforming the control and farmers' practices. At all stages of the crop, the control plot had the lowest leaf area index. Similar trends were observed at all ~~the~~ stages.

Table 6. Effect of nutrient management strategies on leaf area index at various crop growth stages

Treatments	Leaf Area Index			
	30 DAS	**60 DAS**	**90 DAS**	**At harvest**
Control	0.21	2.10	2.80	0.42
100 % NPK (150:60:40 kg ha-1)	0.54	2.60	3.78	0.72
75 % NPK (112.5: 45: 30 kg ha-1)	0.46	2.40	3.20	0.48
75 % NPK + Nano N spray at 30 DAS	0.54	2.80	3.90	0.76
75 % NPK + Nano N spray at 45 DAS	0.51	2.60	3.60	0.72
75 % NPK + Nano N spray at 30 and 45 DAS	0.51	3.20	4.10	0.82
75 % NPK + Nano P spray at 30 DAS	0.49	2.50	3.70	0.66
75 % NPK + Nano P spray at 45 DAS	0.50	2.40	3.60	0.62
75 % NPK + Nano P spray at 30 and 45 DAS	0.51	2.70	3.80	0.74
75 % NPK + Nano N and Nano P spray at 30 DAS	0.52	3.10	4.05	0.80
75 % NPK + Nano N and Nano P spray at 45 DAS	0.49	2.90	4.00	0.78
75 % NPK + Nano N and Nano P spray at 30 and 45 DAS	0.52	3.30	4.20	0.83
SEm±	**0.02**	**0.1**	**0.1**	**0.02**
CD (P = 0.05)	**NS**	**0.22**	**0.4**	**0.07**

According to **Aziz et al. (2016)**, the sprayed nano-fertilizers may have been absorbed through the stomata of wheat leaves and have been translocated within the plant, which could account for the significant increase in the increased leaf area index of wheat plants as influenced by foliar application of Nano N and P fertilisers. Additionally, the enhanced leaf area index could be a result of the high reactivity of nano-fertilizers, which is attributable to their increased specific surface area, increased density, or increased reactivity of these areas on the particle surfaces. These characteristics of nano-scale fertilisers make it easier for plants to absorb them **(Dhoke et al., 2013)**.

Conclusion

Based on the findings of the investigation conducted during the rabi season of 2021–2022 it was possible to draw the conclusion that wheat crops grown under nutrient management practises that included the application of 75% NPK + Nano N and Nano P spray at 30 and 45 DAS one experienced better growth in terms of plant height, tillers m–2, dry matter accumulation, and leaf area index.

Future Scope

The above finding is best on one-year field experimentation. Therefore, ~~in order~~ to arrive at a meaningful recommendation, the further effect of doses and sources of nutrients on growth, yield and nutrient uptake in timely sown wheat needs to be repeated for one more year.

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