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Effect of Conventional and Nano Fertilisers on Growth, Phenology and Nutrient Use Efficiency of Ethiopian Mustard (*Brassica carinata* A. Braun) in North-Western Himalayas

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Abstract

A field experiment comprising ten treatment combinations of conventional and nano fertilisers was conducted at Kangra, Himachal Pradesh, following a randomised complete block design with the Ethiopian mustard variety "Jayanti" during the rabi season 2024-25. Application of 100% recommended dose of nitrogen and phosphorus (RD-NP) and 75% RD-NP recorded taller plants, early flowering and physiological maturity as compared to 50% RD-NP. Similarly, better agronomic and crop recovery efficiency was recorded in 100% RD-NP. Among nano fertilisers, 2 sprays of nano-DAP and 2 sprays each of nano-urea and nano-DAP provided high agronomic and crop recovery efficiency. Further, foliar sprays of nano fertilisers showed positive influence on growth, phenological characteristics, agronomic, as well as crop recovery efficiency. Thus, two sprays each of nano-urea and nano-DAP @ 4mL/litre at 25-30 and 45-50 DAS integrated with application of 60:40:40 kg N, P_2O_5 and K_2O/ha may be economical in Ethiopian mustard in the mid-hills of north-western Himalayas.

Keywords: Agronomic Efficiency, Crop Recovery Efficiency, Ethiopian Mustard, Nano Fertilisers, Phenology

India ranks third globally in the production of oilseeds. Oilseeds, the second largest agricultural commodity in India after cereals, account for nearly 5% of gross national product and 10% of the value of all agricultural products. In India, rapeseed-mustard is grown on an area of 10 million hectares with a total annual production of 13.26 million tonnes and an average yield of 1458 kg/ha. In Himachal Pradesh, rapeseed-mustard is an important oilseed crop grown on an area of over 8.60 thousand hectares with a total production of 4.9 thousand tonnes and an average productivity of 817 kg/ha (Anonymous 2024). Rapeseed and mustard group occupy a significant place in the country among the oilseeds, contributing nearly 23.2% of the cropped oilseeds area and 26.2% of the oilseeds production. However, in India, its productivity is quite less (1458 kg/ha) as compared to other major rapeseed and mustard growing countries, where the world average is 2144 kg/ha. Rapeseed-mustard crops have high nutrient requirements, but they are mainly grown by small and marginal farmers who struggle to access necessary resources. Furthermore, these crops are typically cultivated in soils of low fertility. Consequently, the growth potential of rapeseed-mustard is constrained, despite its high nutrient demands.

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Nutrients are essential parts of chlorophyll, nucleotides, proteins, and enzymes, and therefore support numerous metabolic processes in plants, which ultimately help in improved growth and development (Chandel *et al.* 2022; Chandel *et al.* 2023). Proper supply of plant nutrients plays a vital role in increased yield and sustaining soil health (Sharma & Sharma 2016). In the present scenario, there is a need to adopt sustainable agricultural practices to minimise the adverse impact of indiscriminate use of synthetic fertilisers (Sharma *et al.* 2016). Nanotechnology has become an important field of research in agriculture (Pramanik *et al.* 2020) and has been perceived as a promising technology by the majority of the stakeholders (Mukherjee *et al.* 2019). One of the most promising applications of nanotechnology in agriculture is the use of nano-fertilisers, *viz*. Nano-urea, a nanoscale version of urea, is one of the most widely used nitrogen fertilisers (Jangir *et al.* 2021).

To boost productivity, consistent efforts are being made to develop the high-yielding quality cultivars (Ton *et al.* 2020). Nano particles have a size range of 1-100 nm, and application of nano fertilisers on seed and plants through seed treatment and foliar spray in small quantities has been reported to have a better effect on growth and yield of crops (Akhtar *et al.* 2022). The nanoparticles have properties such as high absorption capacity and increased surface-to-volume ratio, making them a promising plant growth promoter. Nano-scale nutrients can easily infiltrate the plant leaves, initiate nutrient pathways and achieve higher nutrient use efficiency through slow/steady/controlled release of nutrients to the target site of plants. Nanoscale nutrients are taken by plants with two mechanisms, *i.e.* direct uptake or stomatal uptake and secondly by surface absorption. Nano particles slowly release the active nutrient component inside the plant cell, which helps the plant's metabolism to trigger plant growth and development (Singh *et al.* 2017).

The 21st century has brought revolutionary products known as IFFCO nano-urea and nano-DAP, which are essential for preserving the environment and ensuring sustainable food production for future generations. These new liquid fertilisers can enhance crop yields while improving their nutritional quality, all at a much lower cost than conventional fertilisers. Adaptation of modern techniques and management practices can also help to increase the productivity of this crop in Himachal Pradesh.

MATERIALS AND METHODS

A field experiment was conducted during *rabi* 2024-25 at Chaudhary Sarwan Kumar Himachal Pradesh Krishi Vishwavidyalaya, Shivalik Agricultural Research and Extension Centre (SAREC), Kangra, India. The soil of the field experimentation was clay loam in texture having pH of 5.79. The soil was low in available nitrogen (282.24 kg/ha), whereas medium in available phosphorus (18.1 kg/ha) and available potassium (214.1 kg/ha). The experiment consisted of ten combinations. Treatments comprised of combinations of Factor A (100% recommended dose of nitrogen and phosphorus (RD-NP), 75% RD-NP and 50% RD-NP) and Factor B (2 sprays of nano-urea 4mL/litre, 2 sprays of nano-DAP @ 4mL/litre and 2 sprays of nano-urea and 2 sprays of nano-DAP @ 4mL/litre) with one absolute control. The top-dressing of nano fertilisers/foliar spray (in 500 L water/ha) was done at 25-30 and 45-50 DAS (Days after sowing). The experiment was laid out in a randomised complete block design replicated thrice with a plot size of 19.5 m^2. The NPK fertilisers were applied through urea (46%), SSP (16%) and MOP (60%). The recommended dose of fertiliser was 60 kg N, 40 kg P_2O and 40 kg K_2O/ha. Crop received 151.1 mm of rainfall and three irrigations, including pre-sowing, were given. The manual sowing of the "Jayanti" variety was done using the *kera* method, with row spacing of 30 cm and plant-plant spacing of around 15-20 cm. The seed rate used was 5 kg per hectare. The experimental plots were visited on every alternate day after the initiation of flowering. The date on which 50 per cent plants in the net plot had at least one open flower was recorded, and the number of days taken to 50 per cent flowering was calculated from the date of sowing. When stems of all 10 randomly selected plants turned yellow, and siliquae ripened, the crop was considered to attain physiological maturity, and the days from sowing to maturity were counted and recorded as the number of days taken to physiological maturity. Agronomic efficiency indicates kg crop yield increase per kg nutrient applied. During the study, agronomic efficiency was calculated by adopting

the formula of López-Bellido and López Bellido and mathematically, this can be expressed as:

$$\text{Agronomic efficiency} = \frac{\text{Seed yield (kg / ha) in fertilised soil} - \text{seed yield (kg / ha) in unfertilized soil}}{\text{Quantity of fertiliser supplied (kg / ha)}}$$

Crop recovery efficiency indicates that kg increase in nutrient uptake per kg nutrient applied. It was calculated for each primary nutrient and computed by using the following formula:

$$\text{Crop recovery efficiency} = \frac{\text{Nutrient uptake in fertilised soil} - \text{Nutrient uptake in unfertilized soil}}{\text{Amount of nutrients applied}}$$

The data obtained on various crop parameters during the experimentation were statistically analysed for Factorial Randomised Block Design by using the ANOVA (Analysis of variance) techniques as per Cochran and Cox (1957), and were tested by using the t-test at 5 % level of significance. The CD (critical difference) method was used to interpret the significant treatment differences. Data analysis was undertaken in OPSTAT https://opstat.somee.com/opstat/twofactor/fact2.asp software.

RESULTS AND DISCUSSION

The application of conventional and nano fertilisers significantly influences the phenological development of Ethiopian mustard. Fertilisers provide the essential primary nutrients such as N, P and K that help in vegetative and reproductive growth and accelerate germination and flowering of the crop. The data in Table 1 indicate the plant height, number of primary and secondary branches per plant, number of days taken to 50% flowering and days taken to physiological maturity in Ethiopian mustard under different conventional and nano-fertiliser treatments.

Significant variation among RD-NP levels in terms of plant height and number of primary and secondary branches per plant was recorded (Table 1). The application of the 100% RD-NP recorded taller plants (251.5 cm), being at par with 75% RD-NP compared to 50% RD-NP (Table 1). It shows that plant height increases with an increase in the nitrogen and phosphorus levels (by 5.9 cm as RD-NP increases from 75% to 100%). The greater plant height recorded might be attributed to better availability of nutrients in the soil for plant nourishment from a higher dose of nutrients applied, which might have enhanced cell division, elongation, as well as various metabolic processes resulting in increased plant growth (Sharma *et al.* 2014; Noori *et al.* 2023). These results are in close conformity with the findings of Navya *et al.,* (2022), Shilpa *et al.,* (2024) and Thakur *et al.,* (2024). Significantly higher numbers of primary and secondary branches per plant were observed with the application of 100% RD-NP, being at par with 75% RD-NP in primary branches, followed by 50% RD-NP. These results were in close conformity with Pandav *et al.,* (2022) and Goud *et al.,* (2022).

Among nano fertilisers, 2 sprays of nano-urea and 2 sprays of nano-DAP @ 4mL/litre recorded taller plants (250.4 cm), being at par with 2 sprays of nano-DAP @ 4mL/litre. Absolute control recorded smaller plants as compared to the rest of the treatments. Significantly higher numbers of primary (10.6) and secondary branches (20.7) were recorded with 2 sprays of nano-urea and 2 sprays of nano-DAP @ 4mL/litre. This might be due to nano fertilisers having better nutrient absorption and faster uptake, which enhances the plant metabolic activities, which helps in more vigorous branching. These results were in close conformity with Pandav *et al.,* (2022) and Bhedela *et al.,* (2024). Absolute control recorded smaller plants and less number of primary and secondary branches per plant.

The application of the 100% RD-NP attains 50% flowering (108.3) and physiological maturity (173.2) early, being at par with 75% RD-NP compared to 50% RD-NP (Table 1). 100% RD-NP contributes an adequate supply of nutrients, which play major roles in the physiological development of plants (Sharma *et al.* 2018) and are the main reason for early flowering and physiological maturity. The results of this investigation align with the findings of Rana *et al.,* (2021), Shilpa *et al.,* (2022) and Prajapati *et al.,* (2024).

Among nano fertilisers, 2 sprays of nano-urea and 2 sprays of nano-DAP @ 4mL/litre showed early 50% flowering (108.7) and physiological maturity (173.4) than 2 sprays of nano-urea @ 4mL/litre and 2 sprays of nano-DAP @ 4mL/litre due to the combinations of both nano fertilisers provides better nutrient availability

Table 1. Effect of conventional and nano fertilisers on plant height, branches, 50% flowering and physiological maturity of Ethiopian mustard

Treatments	Plant height (cm)	Primary branches	Secondary branches	Days to 50% flowering	Days to Physiological Maturity
FACTOR A					
100% RD-NP	251.5	11.1	21.0	108.3	173.2
75% RD-NP	245.6	10.1	17.6	109.2	174.4
50% RD-NP	229.2	8.6	17.0	110.6	176.6
SE m±	2.4	0.4	0.5	0.3	0.4
LSD (*P*=0.05)	7.2	1.1	1.6	1.0	1.2
FACTOR B					
2 sprays of nano-urea*	232.7	9.2	15.5	109.7	175.7
2 sprays of nano DAP *	243.2	9.9	19.5	109.8	175.1
2 sprays of nano-urea and nano-DAP*	250.4	10.6	20.7	108.7	173.4
SE m±	2.4	0.4	0.5	0.3	0.4
LSD (*P*=0.05)	7.2	1.1	1.6	NS	1.2
Control vs Rest of Treatments					
Absolute Control (Water spray)	221.2	6.5	10.4	113.0	179.3
Others	242.1	9.9	18.5	109.4	174.7
SE m±	3.1	0.5	0.7	0.4	0.5
LSD (*P*=0.05)	9.3	1.4	2.0	1.3	1.5

* 4mL/L @ 25-30 DAS and 45-50 DAS

Table 2. Effect of conventional and nano fertilisers on the agronomic efficiency of Ethiopian mustard

Treatments	Nitrogen	Phosphorus	Potassium	Total NPK
FACTOR A				
100% RD-NP	9.4	14.0	14.1	4.0
75% RD-NP	10.1	14.6	11.1	3.9
50% RD-NP	10.5	17.2	8.4	3.5
SE m±	0.7	1.1	0.7	0.2
LSD (*P*=0.05)	NS	NS	2.2	NS
FACTOR B				
2 sprays of nano-urea*	7.0	13.0	8.3	2.7
2 sprays of nano DAP *	10.2	15.2	11.4	3.9
2 sprays of nano-urea and nano-DAP*	12.7	17.5	13.9	4.9
SE m±	0.7	1.1	0.7	0.2
LSD (*P*=0.05)	2.3	3.4	2.2	0.8

* 4mL/L @ 25-30 DAS and 45-50 DAS

that helps in faster physiological development of crop. Absolute control took a longer time to attain 50% flowering (113.0) and physiological maturity (179.3).

1. Agronomic Efficiency

Agronomic efficiency is significantly influenced by the recommended dose of nitrogen and phosphorus and nano fertilisers for primary nutrients N, P and K (Table 4).

Agronomic efficiency of nitrogen and phosphorus was higher at 50% RD-NP than at 75% RD-NP and 100% RD-NP, which can be ascribed to the law of diminishing returns, *i.e.* less response at a higher level (Chandel *et al.* 2023), whereas agronomic efficiency of potassium was and total NPK were high at 100% RD-NP (Table 2).

Among nano fertilisers, 2 sprays of nano-urea and 2 sprays of nano-DAP @ 4mL/litre recorded higher values of agronomic efficiency, being at par with 2 sprays of nano-DAP @ 4mL/litre. The reason for higher agronomic efficiency with foliar spray of nano fertilisers is due to the smaller particle size and higher surface

Table 3. Effect of conventional and nano fertilisers on crop recovery efficiency of Ethiopian mustard

Treatments	Nitrogen	Phosphorus	Potassium	Total NPK
FACTOR A				
100% RD-NP 75% RD-NP	0.68 0.70	0.17 0.16	0.44 0.17	0.47 0.41
50% RD-NP	0.73	0.15	0.09	0.32
SE m±	0.05	0.01	0.04	0.03
LSD (*P*=0.05)	NS	NS	0.13	0.09
FACTOR B				
2 sprays of nano-urea*	0.47	0.11	0.12	0.26
2 sprays of nano DAP *	0.70	0.16	0.21	0.42
2 sprays of nano-urea and nano-DAP*	0.94	0.22	0.37	0.52
SE m±	0.05	0.01	0.04	0.03
LSD (*P*=0.05)	0.15	0.02	0.13	0.09

* 4mL/L @ 25-30 DAS and 45-50 DAS

area, which increases the absorption rate of the fertiliser through stomatal openings and leads to efficient uptake of the nutrient, which helps in increasing production of the crop as compared to conventional fertilisers. These results were in close conformity with (Rehab *et al.* 2018) and (Upadhayay *et al.* 2023).

2. Crop Recovery Efficiency

Crop recovery efficiency indicates how efficiently a crop utilises applied nutrients for growth and development. Crop recovery efficiency was higher at 100% RD-NP than at 75% RD-NP and 50% RD-NP, except for nitrogen. The reason is that an adequate supply of nutrients increases the fertiliser's effect period.

Among nano-fertiliser treatments, 2 sprays of nano-urea and 2 sprays of nano-DAP @ 4mL/litre recorded higher values of Crop recovery efficiency (Table 3). This is because nanoparticles have a greater surface area and are of a smaller size, which helps them to more readily enter the plants and improve nitrogen and phosphorus uptake (Rai *et al.* 2012).

The value of nitrogen ranged between 0.47-0.94, for phosphorus ranged between 0.11-0.22, for potassium ranged between 0.12-0.37 and for total NPK ranged between 0.26-0.52.

CONCLUSION

Based on the findings of the investigation, it can be concluded that application of 100% recommended dose of nitrogen and phosphorus (RD-NP) and that of 2 sprays each of nano-urea and nano-DAP @ 4mL/litre recorded taller plants, more number of primary and secondary branches per plant along with minimum days to flowering and physiological maturity besides numerically high crop recovery efficiency of phosphorus, potassium and total NPK and agronomic efficiency of potassium and total NPK. Hence, application of 100% RD-NP with 2 sprays each of nano-urea and nano-DAP @ 4mL/litre would be beneficial to achieve better growth and development in Ethiopian mustard in the mid-hills of north-western Himalayas.

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