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Effect of conjoint use of conventional and nano-fertilisers on Ethiopian mustard (*Brassica carinata*) in north-western Himalayas

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ABSTRACT

The present experiment was conducted to study the effect of conventional and nano-fertilisers on growth, yield attributes and yield of Ethiopian mustard (*Brassica carinata* A. Brown) (variety Jayanti) in north-western Himalayas during winter (*rabi*) season of 2023–24 and 2024–25 at Shivalik Agricultural Research and Extension Centre, Kangra, Himachal Pradesh. The experiment was laid out in a factorial randomised block design (F-RBD) involving three levels of RD-NP (Recommended dose of nitrogen and phosphorus), viz. 100%, 75% and 50% RD-NP and three sprays of nano-fertilisers, viz. two-sprays of nano-urea @4 mL/L at 25 and 45 DAS (days after sowing), two sprays of nano-DAP @4 mL/L at 25 and 45 DAS, and two sprays of nano-urea + nano-DAP (4 mL/L each) at 25 and 45 DAS, and one absolute control (water spray). The pooled analysis recorded that 100% RD-NP had significantly higher values of plant height, number of primary and secondary branches/plant, siliquae/plant, seeds/siliqua, seed yield and biological yield as compared to the treatments 75% RD-NP and 50% RD-NP. Among nano-fertilisers, two sprays of nano-urea + nano-DAP @4 mL/L (each) recorded higher values of plant height, number of primary and secondary branches/plant, siliquae/plant, seeds/siliqua, seed yield and biological yield than their individual application. The results indicated that foliar sprays of nano-fertilisers showed positive influence on growth, yield attributes and yield in Ethiopian mustard. Thus, two spray of nano-urea + nano-DAP @4 mL/L each at 25 and 45 DAS with application of 60 kg N, 40 kg P_2O_5 and 40 kg K_2O/ha may be advisable in mid-hills of north-western Himalayas.

Keywords: Benefit: cost ratio, Gross returns, Nano-DAP, Nano urea, Yield

Rapeseed and mustard group occupy 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 (1,458 kg/ha) as compared to other major rapeseed and mustard growing countries where the world average is 2,144 kg/ha (Anonymous 2024).

Rapeseed-mustard crops have high nutrient requirements, but mainly grown by small and marginal farmers who struggle to access necessary resources. Furthermore, these crops are cultivated typically in soils of low fertility. Consequently, the growth potential of rapeseed-mustard is constrained, despite its high nutrient demands (Mankotia and Sharma 1997; 1998).

Nanotechnology has become an important field of research in agriculture (Pramanik *et al.* 1996). It is perceived as promising technology by 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, one of the most widely used nitrogen fertilisers (Jangir *et al.* 2021). Nano particles have size range of 1–100 nm and application of nano-fertilisers on seed and plants through seed treatment and foliar spray in small quantities have been reported to have better effect on growth and yield of crops (Akhtar *et al.* 2022). The IFFCO has developed nano-urea and nano-DAP fertilisers, which are capable of enhancing crop yields while improving their nutritional quality. Nano scale nutrients can easily infiltrate the plant leaves, initiate nutrient pathways and achieve higher nutrient use efficiency through slow/steady/control release of nutrients to the target site of plants (Singh *et al.* 2017). Hence, the present study was aimed to increase the productivity of Ethiopian mustard (*Brassica carinata* A. Brown) in Himachal Pradesh by evaluating the effect of conventional and nano-fertilisers on its growth, yield attributes and yield.

MATERIALS AND METHODS

A field experiment was conducted during winter (*rabi*)

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season of 2023–24 and 2024–25 at Shivalik Agricultural Research and Extension Centre, Kangra (32°09′ N, 76°22′ E; at an elevation of 700 m amsl), Himachal Pradesh. The soil of experimental field was clay loam in texture having soil *p*H 5.79, low in available nitrogen (276.0 kg/ha), medium in available phosphorus (18.1 kg/ha) and available potassium (214.0 kg/ha). The experiment was laid out in factorial randomised block design (F-RBD) replicated thrice in plot size of 19.5 m^2. The experiment consisted of 10 treatment combinations, viz. factor A [100% RD-NP (Recommended dose of nitrogen and phosphorus), 75% RD-NP and 50% RD-NP] and factor B (Two sprays of nano-urea 4 mL/L, two sprays of nano-DAP @4 mL/L and two sprays of nano-urea + nano-DAP @4 mL/L each) and one absolute control. Foliar spray of nano-fertilisers (500 L water/ha) was done at 25 and 45 days after sowing (DAS). The NPK (60 kg N, 40 kg P_2O and 40 kg K_2O/ha) fertilisers were applied through urea, SSP and MOP. Full recommended dose of K_2O was applied uniformly in all the treatments. The 'Jayanti' variety of mustard was manually sown using *kera* method at seed rate 5 kg/ha maintaining the row spacing of 30 cm and approximately 15 cm plant-plant spacing. Various observations related to the growth, yield attributing characteristics and seed yield were recorded. To find out the most profitable treatment, economics of different treatments were worked out in terms of gross and net returns of the crop. Treatmentwise benefit:cost (B:C) ratio was calculated to ascertain economic viability.

Statistical analysis: The data obtained on various crop parameters during the experimentation were statistically analysed for factorial randomised block design (F-RBD) by using the ANOVA (Analysis of variance) techniques as per Cochran and Cox (1957) and were tested by using t-test at 5% level of significance. The CD was used to interpret the significant treatment differences. Data analysis was undertaken in OPSTAT software. When the data were similar during both the years, a pooled analysis was carried out and presented.

RESULTS AND DISCUSSION

Growth attributes: The application of 100% RD-NP recorded significant increase in growth attributes of Ethiopian mustard, including plant height (249.0 cm), number of primary branches/plant (10.7) and secondary branches/plant (21.2) (Table 1). The application of 100% RD-NP being at par with 75% RD-NP recorded the significantly higher plant height (249.0 cm) over 50% RD-NP. The 75% RD-NP and 50% RD-NP were at par with each other. The higher plant height recorded might be attributed due to the more availability of nutrients in the soil for plant nourishment from higher dose of nutrients applied which might have enhanced cell division, elongation as well as various metabolic processes resulting in increased the plant height. These results were in close conformity with Goud

Table 1 Effect of conventional and nano-fertilisers on growth and yield attributes of Ethiopian mustard (Pooled data of 2 years)

Treatments	Plant height (cm)	Primary branches/ plant	Secondary branches/ plant	Siliquae/ plant	Seeds/ siliqua	Test weight (g)
Factor A: RD-NP levels						
F_1 100% RD-NP	249.0	10.7	21.1	427.8	12.6	3.98
F_2 75% RD-NP	243.5	10.0	18.7	397.9	12.5	3.88
F_3 50% RD-NP	236.8	9.1	18.1	373.4	11.9	3.80
SEm ±	3.4	0.4	0.7	14.9	0.2	0.04
CD (*p*=0.05)	10.0	1.3	2.2	44.4	0.7	0.12
Factor B: Nano-fertilisers						
S_1 Two sprays of nano-urea*	236.4	9.4	17.6	387.6	12.2	3.84
S_2 Two sprays of nano DAP*	244.2	9.9	19.6	402.0	12.4	3.86
S_3 Two sprays of nano-urea and nano-DAP*	248.8	10.5	20.7	409.6	12.4	3.97
SEm ±	3.4	0.4	0.7	14.9	0.2	0.04
CD (*p*=0.05)	10.0	1.3	2.2	NS	NS	0.12
Control vs Rest of the treatments						
Absolute control (Water spray)	222.7	6.7	12.5	296.6	11.7	3.74
Others	243.1	9.9	19.3	399.7	12.3	3.89
SEm ±	4.3	0.5	0.9	19.3	0.3	0.05
CD (*p*=0.05)	13.0	1.6	2.8	57.3	0.9	0.16

*4 mL/L @25 and 45 days after sowing; NS, Non-significant; RD-NP, Recommended dose of nitrogen and phosphorus.

et al. (2022), Navya *et al.* (2022) and Damor *et al.* (2024). Significantly more number of primary (10.7) and secondary branches/plant (21.2) were observed with the 100% RD-NP being at par with 75% RD-NP followed by 50% RD-NP. These results were in close conformity with Shilpa *et al.* (2022) and Damor *et al.* (2024).

Absolute control recorded lower plants height as compared to the rest of the treatments. Among nano-fertilisers, two sprays of nano-urea + nano-DAP @4 mL/L each recorded significantly taller plants (248.8 cm) being at par with two sprays of nano-DAP @4 mL/L which was also at par with two sprays of nano-urea @4 mL/L. Significantly, more number of primary (10.5) and secondary branches (20.7) were recorded with two sprays of nano-urea + nano-DAP @4 mL/L each. This might be due to nano-fertilisers have better nutrient absorption and faster uptake that enhances the plant metabolic activities and enhances photosynthesis which helps in more vigourous growth and branching which directly helps in the more plant height and maximum number of branches/plant. These results were in close conformity with Pandav *et al.* (2022), Choudhary *et al.* (2023) and Bhedela *et al.* (2024). Bhargavi and Sundari (2023) and Sarkar *et al.* (2024) also reported that the nano-urea promotes and enhances photosynthetic activity and improves nutrient uptake and absorption that ultimately increases the number of primary and secondary branches/plant (Kumar *et al.* 2021). Absolute control recorded shorter plants and less number of primary and secondary branches/plant as compared to the rest of the treatments.

Yield attributes: Application of 100% RD-NP recorded significant increase in yield-related characteristics of Ethiopian mustard, including siliquae/plant (427.8), seeds/siliqua (12.6) and 1000-seed weight (3.98 g) over 50% RD-NP (Table 1). These findings significantly outperformed both the 75% RD-NP and 50% RD-NP treatments. The application of 100% RD-NP being at par with 75% RD-NP and 50% RD-NP recorded the significantly higher value of siliquae/plant (427.8), seeds/siliqua (12.6) and 1000-seed weight (3.98 g). The provision of sufficient chemical fertilisers effectively addressed the crop's nutritional demands, consequently augmenting the yield attributing characteristics that ultimately leads to the higher yield potential and by improving the use of essential nutrients and better nitrogen availability can improve the overall crop growth and yield attributing components. The application of 100% RD-NP ensured the proper supply of critical nutrients like NP in adequate levels that are important for diverse physiological processes such as cell division and photosynthesis that encompassing growth, development and reproductive phases in the plant, facilitated improved plant growth attributes that mainly contributes to yield of the crop (Tomar *et al.* 2018). Absolute control recorded significantly lower value of yield attributes as compared to the rest of the treatments.

Among nano-fertilisers, two sprays of nano-urea + nano-DAP @4 mL/L each recorded significantly higher value of siliquae/plant (409.6), seeds/siliqua (12.4) and 1000-seed weight (3.97 g) being at par with other two treatments. Nano-fertilisers helps in the better nutrient absorption by plant cells that ultimately results in the better growth promoting to vigorous growth and more yield attributing characters in the plant. The main reason behind more yield attributing characters was the optimum availability of the nutrients with foliar application of nano-fertilisers extended the nutrient delivery for a longer period helps in the siliqua formation stage enhances number of flowers thus ultimately improving ovule fertilisation and leading to a higher number of siliquae/plant and seeds/siliqua (Damor *et al.* 2024). These results were in close conformity with Navya *et al.* (2022), Sharma *et al.* (2023) and Damor *et al.* (2024).

Yield: Seed yield increased significantly by 9.4% (1,987 kg/ha) and 7.4% (1,568 kg/ha) with 100% RD-NP compared to 75% RD-NP in 2023–24 and 2024–25, respectively (Table 2). On pooled mean basis, application of 100% RD-NP (1,778 kg/ha) recorded more seed yield of 8.6, and 23.5% over 75% RD-NP and 50% RD-NP. The application of 100% RD-NP ensures adequate nutrient supply and availability enhacing the efficiency of photosynthesis, which results in taller plants with high dry matter accumulation promoting number of primary and secondary branches with higher number of siliquae/plant and seeds/siliqua resulting in higher yields and stable seed production. These results were in close conformity with Anushka *et al.* (2022), Navya *et al.* (2022) and Chudasama *et al.* (2024).

Foliar application of two sprays of nano-urea + nano-DAP @4 mL/L each recorded significantly more seed yield by 4.4 and 7.6% as compared to sprays of nano-DAP @4 mL/L during 2023–24 and 2024–25, respectively. On mean basis, application of two sprays of nano-urea + nano-DAP @4 mL/L each (1,714 kg/ha) recorded more seed yield of 5.8 and 12.6% over two sprays of nano-DAP @4 mL/L and two sprays of nano-urea @4 mL/L, respectively. Nano-fertilisers improves the yield and yield attributing characters because of more surface to volume ratio of nano-fertilisers that enhances more nutrient uptake and lower nutrient losses. These results were in close conformity with Goud *et al.* (2022) and Pandav *et al.* (2024).

Application of 100% RD-NP recorded significantly higher biological yield of 8,893 kg/ha and 6,331 kg/ha which was 3.2 and 5.1% more over 75% RD-NP during 2023–24 and 2024–25, respectively. On mean basis, application of 100% RD-NP (7,612 kg/ha) recorded more biological yield of 6.5, and 20.5% over 75% RD-NP and 50% RD-NP, respectively. This might be due to use of 100% recommended dose of nitrogen and phosphorus that increases vegetative growth and biomass during the crop period and resulting in stronger plants with more foliage, thicker stems thus ultimately increase biological yield (Rathore *et al.* 2019). These results were in close conformity with Baghla and Sharma (2023), Anushka *et al.* (2022) and Navya *et al.* (2022).

Application of two sprays of nano-urea + nano-DAP @4 mL/L each recorded significantly higher biological yield of 8,197 kg/ha and 6,345 kg/ha which was 8.8 and 4.4% more over two sprays of nano-DAP @4 mL/L during 2023–24

Table 2 Effect of conventional and nano-fertilisers on seed yield and biological yield of Ethiopian mustard

Treatments	Seed yield (kg/ha)			Biological yield (kg/ha)		
	2023–24	2024–25	Pooled	2023–24	2024–25	Pooled
Factor A: RD-NP levels						
F_1 100% RD-NP	1,987	1,568	1,778	8,893	6,331	7,612
F_2 75% RD-NP	1,816	1,459	1,637	8,230	6,060	7,145
F_3 50% RD-NP	1,558	1,319	1,439	7,057	5,569	6,313
SE m ±	63	30	49	300	84	235
CD (p=0.05)	188	89	146	892	250	699
Factor B: Nano-fertilisers						
S_1 Two sprays of nano-urea*	1,721	1,320	1,521	8,043	5,580	6,812
S_2 Two sprays of nano DAP*	1,780	1,458	1,619	7,940	6,035	6,988
S_3 Two sprays of nano-urea and nano-DAP*	1,859	1,569	1,714	8,197	6,345	7,271
SE m ±	63	30	49	300	84	235
CD (p=0.05)	NS	89	146	NS	250	NS
Control vs Rest of the treatments						
Absolute control (Water spray)	1,156	1,004	1,080	5,679	5,019	5,349
Others	1,787	1,449	1,618	8,060	5,987	7,024
SE m ±	82	39	63	388	109	304
CD (p=0.05)	243	115	188	1,152	322	902

*4 mL/L @25 and 45 days after sowing; NS, Non-significant; RD-NP, Recommended dose of nitrogen and phosphorus.

and 2024–25, respectively. On mean basis, application of two sprays of nano-urea + nano-DAP @4 mL/L each (7,271 kg/ha) recorded more biological yield of 4.0 and 6.7% over two sprays of nano-DAP @4 mL/L and two sprays of nano-urea @4 m/L, respectively. Nano-fertilisers efficiently release nutrients and support photosynthesis by obtaining sufficient amounts of chlorophyll-protein complex to capture light. Additionally, crops bare less stress that results in the increased growth and yield (Babu *et al.* 2022). This might be due to the use of combined foliar application of nano-urea and nano-DAP supply adequate nutrient to the plant which helps in increasing vegetative growth and biomass during the

Table 3 Effect of conventional and nano-fertilisers on economics of Ethiopian mustard (2023–24 and 2024–25)

Treatments	Cost of cultivation (₹/ha)		Gross returns (₹/ha)		Net returns (₹/ha)		B:C	
	2023–24	2024–25	2023–24	2024–25	2023–24	2024–25	2023–24	2024–25
Factor A: RD-NP levels								
F_1 100% RD-NP	31,463	32,063	112,265	93,296	80,802	61,233	2.56	1.90
F_2 75% RD-NP	30,577	31,177	102,604	86,811	72,027	55,634	2.35	1.78
F_3 50% RD-NP	29,690	30,290	88,027	78,481	58,407	48,191	1.97	1.59
Factor B: Nano-fertilisers								
S_1 Two sprays of nano-urea*	28,920	29,520	97,236	78,540	68,316	49,020	2.36	1.66
S_2 Two sprays of nano DAP*	31,800	32,400	100,570	86,751	68,770	54,351	2.16	1.67
S_3 Two sprays of nano-urea and nano DAP*	33,720	34,320	105,033	93,356	71,313	59,036	2.11	1.72
Control vs Rest of the treatments								
Absolute control (Water spray)	25,600	26,200	65,314	59,738	39,714	33,538	1.55	1.28
Others	31,028	31,628	100,965	86,206	69,937	54,577	2.25	1.72

*4 mL/L @ 25 and 45 days after sowing; B:C, Benefit:cost ratio; RD-NP, Recommended dose of nitrogen and phosphorus.

crop period and resulting in more population of plants with more foliage and strong stems thus ultimately increasing stover yields. These results were in close conformity with Goud *et al.* (2022) and Pandav *et al.* (2024).

Economics: Application of 100% RD-NP accured high cost of cultivation (₹31,463/ha, ₹32,063/ha), gross returns (₹112,265/ha, ₹93,296/ha), net returns (₹80,802/ha, ₹61,233/ha) and B:C ratio of 2.56 and 1.90 as compared to 75% RD-NP and 50% RD-NP during 2023–24 and 2024–25, respectively (Table 3). This might be due to the higher dose of nitrogen and phosphorus promoted plant growth and enhanced seed yield which led to better economic returns despite higher input costs.

Among nano-fertilisers, two sprays of nano-urea + nano-DAP @4 mL/L each realised more cost of cultivation (₹33,720/ha, ₹34,320/ha), gross returns (₹105,033/ha, ₹93,356/ha), net returns (₹71,313/ha, ₹59,036/ha) and lower B:C ratio of 1.72 as compared to 75% RD-NP and 50% RD-NP during 2023–24 and 2024–25 whereas higher B:C ratio of 2.36 in 2023–24 was observed with two sprays of nano urea because of its low cost of cultivation despite lower returns.

The pooled analysis of two-year data summarised that the application of 100% recommended dose of nitrogen and phosphorus significantly enhanced the growth attributes and yield attributes, viz. plant height (249.0 cm), number of primary (10.7) and secondary branches/plant (21.1), siliquae/plant (427.8), seeds/siliqua (12.6) and 1000-seed weight (3.98 g) that resulted in achieving significantly more seed yield (1,778 kg/ha), biological yield (7,612 kg/ha), net returns and B:C ratio as compared to the lower RD-NP levels. Among nano-fertilisers treatments, two sprays of nano-urea + nano-DAP @4 mL/L each significantly enhanced the growth, yield attributes, seed yield (1,714 kg/ha), biological yield (6,812 kg/ha) and net returns as compared to their individual application. Hence, application of 100% RD-NP with two sprays of nano-urea + nano-DAP @4 mL/L each at 25 and 45 DAS may be recommended to get higher productivity by farmers in mid-hills of north-western Himalayas.

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