Impact of NPKS and foliar nano fertilizer application of Indian mustard (*Brassica juncea* L.) growth in Himachal Pradesh's mid hill region

Abstract

The present study was performed during *Rabi* season of 2022-23 at Research Farm, School of Agriculture, Abhilashi University, Chail Chowk, Mandi (H.P.) India. The experimental design utilized a Randomized Block Design (RBD) with eight different treatments, replicated three times. T_1 was the absolute control with no fertilizers or chemicals. T_2 used 100% NPK and sulfur (S) with zinc (Zn) at 5 kg ha^{-1}. T_3 included 100% NPK and S with bio stimulants. T_4 applied 100% NPK and S with Nano Zn spray at 40 days after sowing (DAS). T_5 used 75% NPK and S with NPK consortia. T_6 applied 75% NPK and S with Nano nitrogen (N) spray at 40 DAS. T_7 combined 75% NPK and S with both Nano N and Nano Zn sprays at 40 DAS. T_8 used 75% NPK and S with NPK consortia and Nano Zn spray at 40 DAS. The highest values of growth attribute viz. [highest plant height (cm), and dry matter accumulation (g m^{-2})], yield attributes and yield viz. [Number of siliquae plant^{-1}, Siliquae length (cm), Number of seed siliquae plant^{-1}, 1000 seed weight, weight of siliquae plant^{-1}, seed yield (q ha^{-1}), stover yield (q ha^{-1}) and biological yield (q ha^{-1}) was found with application of 100% NPK and S with Nano Zn spray at 40 DAS. While, some attributes namely- test weight (g), number of seed siliquae plant^{-1}, harvest index (%) was found non-significant. However, the lowest values for all parameters were observed under treatment T_1 (absolute control). Therefore, using nanofertilizers to accelerate plant growth and production can lead to new developments in agricultural practice. However, the kind of plant species, stage of growth, and type of nanomaterial all affect how plants react to nanofertilizers.

Keywords: Nano nitrogen, Nano zinc, NPK consortia, Bio-stimulant, Sulphur.

Introduction

"*Brassica juncea*, commonly known as brown mustard, Chinese mustard, Indian mustard, leaf mustard, oriental mustard and vegetable mustard, is a species of mustard plant. Mustard is belonging to the family *Brassicaceae* (*Cruciferae*) and chromosome number of mustard is 2 n=18. Oilseeds *Brassica*, comprising eight different species *viz.* Indian mustard *Toria*, Yellow *sarson*, Brown *sarson*, *Gobhi sarson*, *Karan rai*, Black mustard and *Taramira*, arecultivated commercially in India. *Brassica juncea* (L.) Czenj and Cosson is mainly grown in the states of Rajasthan, Uttar Pradesh, Haryana, Punjab, Madhya Pradesh, Bihar, West Bengal and Gujarat. Rapeseed and mustard thrive well under both irrigated as well as rainfed conditions. Being more responsive to fertilizers, it offers better returns under irrigated conditions. The oil content and quality of oilseeds *Brassica* varies among the species with the management practices. The green leaves, seed and oil of oilseeds *Brassica* are used in preparation of various edible items including vegetables, pickles and flavouring agent (as condiments). Its oil is considered as one of the best edible oils for cooking purpose. Further its oil cake and green leaves are used as manure and cattle feed" Chauhan et al. (2011).

"Biostimulants are substances that promote plant growth when applied in small quantities. They are also known as metabolic enhancers. Components from seaweed, such as macro- and microelement nutrients, amino acids, vitamins, cytokinins, auxins, and abscisic acid (ABA)-like growth substances, affect cellular metabolism in treated plants, leading to enhanced growth and crop yield". (Zhang and Schmidt. 1997; Durand et al. 2003; Stirk et al. 2003; Ordog et al. 2004) "Seaweed extracts are bioactive at low concentrations, diluted as 1:1000 or more" (Crouch and van Staden, 1993). "Although many of the various chemical components of seaweed extracts and their modes of action remain unknown, it is plausible that these components exhibit synergistic activity" Fornes et al. (2002). "It has been discovered that seaweed works well to increase crop output, insect resistance, and resilience to frost in cereals, oilseeds, vegetables, fruits, and flowers" (Vernieri et al., 2005).

"Nano fertilizers have properties that improve plant performance, such as ultra-high absorption, increased production, and a rise in leaf surface area. Additionally, the controlled release of nutrients helps prevent eutrophication and pollution in water resources. Replacing traditional fertilizers with nano fertilizers is beneficial because they release nutrients into the soil steadily and in a controlled way, thus preventing water pollution" Moaveni and Kheiri (2011). "The use of nano fertilizers not only causes increased use efficiency through ultra-high absorption of the nutrients, increase in photosynthesis caused by expansion in surface area of the leave but also reduce the toxicity generated due to over application in the soil as well as reduces the split application of fertilizer. Nano fertilizers and nanocomposites can be used to control the release of nutrients from the fertilizer granules so as to improve the nutrient use efficiency while preventing the nutrient ions from either getting fixed or lost to the environment" (Vernieri et al., 2005).

"Biofertilizers are grouped into different types on the basis of their functions and mode of action. The commonly used biofertilizers are nitrogen fixer (N-fixer), potassium solubilizer (K-solubilizer), phosphorus solubilizer (P-solubilizer), and plant growth promoting rhizobacteria (PGPR). Biofertilizers play an important role in improving soil fertility and enhancing crop yield. When applied to the soil, they participate in nutrient cycling and improve the soil structure and crop productivity. Biofertilizers, also called microbial inoculants, are organic products containing specific microorganisms, which are derived from plant roots and root zones. They have been shown to improve the growth and yield of the plant by 10–40%. Overuse of conventional fertilizers is a globally followed practice to meet plant nutrient needs. However, the efficiency of fertilizer use in crops rarely exceeds 30–35%, which is due to the loss of nutrient through leaching, evaporation and fixation" Mahmud et al. (2021). "Therefore, nano-fertilizers have gained momentum over the decade to make fertilizer use more efficient and facilitate fertilizer application. However, research has evolved over a decade from laboratory studies and concentric pot experiments. Few systematic studies have been conducted so far to demonstrate the effects of nano-fertilizers or the combination of nano-fertilizers with conventional fertilizers on crop yield and economics under the field conditions" Kah et al. (2018), Hu and Xianyu, (2021) Upadhyay et al. (2023).Thus, accelerating plant growth and productivity by application of nano fertilizers can open new perspectives in agricultural practice

Materials and Methods

A present field experiment was conducted during Rabi 2022-23 at the Research Farm, School of Agriculture, Abhilashi University, Mandi (H.P.) which is located at 77^0 East longitude and 31^0 North latitude and has an altitude of 1500 meters. The research was carried out in both the field and the lab in Abhilashi University's Department of Agronomy, School of Agriculture. Before the start of experiment, composite soil samples from a depth of 15 cm were collected from each of the three replications. These samples were subsequently processed and analyzed to determine their chemical properties. pH (1:2.5, soil: water suspension) was measured using the Potentiometric method as described by Jackson (1973). Electrical conductivity (dS m^{-1}) (1:2.5 soil: water extract) was determined using an EC meter following Jackson (1973). Organic carbon (%) was analyzed using the Rapid titration method by Walkley and Black (1934). Available nitrogen (kg ha^{-1}) was assessed using the Alkaline permanganate method according to Subbiah and Asija (1956). Available phosphorus (kg ha^{-1}) was extracted using Olsen's method with 0.5 N $NaHCO_3$ at pH 8.5, as per Olsen et al. (1954). Available potassium (kg ha^{-1}) was extracted with normal neutral ammonium acetate and measured with a pH meter at pH 7.0, as described by Jackson (1973). Available zinc (mg kg^{-1}) and available sulfur (ppm) were estimated using DTPA extractant and Atomic Absorption Spectroscopy (AAS), Lindsay and Norvell (1978). The cropping history of the field was thoroughly reviewed for the three years preceding the current experiment to provide context for the results. In 2019, the field was cultivated with maize during the Kharif season and barley during the Rabi season. In 2020, rice was grown in the Kharif season, wheat in the Rabi season, and maize during the Zaid season. In 2021, soybean was planted in the Kharif season, pea in the Rabi season, and moong in the Zaid season. For 2022, the field was sown with guinea grass in the Kharif season, an experimental crop (mustard) in the Rabi season and remained fallow during the Zaid season.

The experiment was conducted to evaluate the effects of various treatments on crop performance. The study was carried out on a total area of 222 m^2, with sowing done on 10 November 2022 using the line sowing method. The experimental design utilized a Randomized Block Design (RBD) with eight different treatments, replicated three times. T_1 was the absolute control with no fertilizers or chemicals, T_2 used 100% NPK and sulfur (S) with zinc (Zn) at 5 kg ha^{-1}, T_3 included 100% NPK and S with bio stimulants, T_4 applied 100% NPK and S with Nano Zn spray at 40 days after sowing (DAS), T_5 used 75% NPK and S with NPK consortia, T_6 applied 75% NPK and S with Nano nitrogen (N) spray at 40 DAS, T_7 combined 75% NPK and S with both Nano N and Nano Zn sprays at 40 DAS and T_8 used 75% NPK and S with NPK consortia and Nano Zn spray at 40 DAS. Each treatment was applied to a plot size of 3.7 × 2.5 meters (gross) and 2.7 × 1.5 meters (net), with a spacing of 25 cm between rows. The main irrigation channel was 1.5 meters wide, while the sub-irrigation channel was 1 meter wide, and the bund was 0.7 meters high. The seed rate was 5 kg per plot, and the variety used was Gold Madel. The recommended dose of N, P, K, and S for the crop was 120:60:40:20 kg ha^{-1}, with Zinc Sulphate monohydrate applied at 20 kg ha^{-1}.

The observations to be recorded include plant height (cm), dry matter accumulation (g m^{-2}), number of siliquae per plant, siliquae length (cm), number of seeds per siliquae, weight of siliquae per plant, seed yield (q ha^{-1}), stover yield (q ha^{-1}) biological yield (q ha^{-1}), and harvest index (%). The results obtained from various chemical parameters of the initial experimental soil are given in Table 1.

Table 1 Initial chemical parameters of the experimental soil

S.N.	Particulars	Content
1	pH (1:2.5, soil: water suspension)	5.4
2	Electrical conductivity (dS m^{-1}) (1:2.5 soil: water extract)	0.008
3	Organic carbon (%)	0.96
4	Available N (kg ha^{-1})	247.19
5	Available P (kg ha^{-1})	22.64
6	Available K (kg ha^{-1})	270.03
7	Available Zn (mg kg^{-1})	0.44
8	Available S(ppm)	12.69

Results and Discussion

Growth parameters

Plant height (cm)

The data pertaining to plant height recorded at different growth stages has been presented in Table 2 and in Fig. 1. At 30 DAS, the plant height was found non-significant. Whereas, at 60, 90 DAS and at harvest stage of the mustard crop, the highest plant height was observed in treatment T_4 (100% NPK and S+ NANO Zn spray at 40 DAS) which were higher over rest of the other treatments, while, treatment T_7 (75% NPK and S+ Nano N spray at 40 DAS + Nano Zn spray at 40 DAS) was statistically on par with treatment. However, the lowest plant height was noted under treatment T_1 (Absolute control) at various growth stages of mustard crop. The foliar application of nano fertilizers was effective in promoting plant growth. This might suggest that urea, when used alone or in combination with nano nutrients, might positively influence plant growth. Nano fertilizers enhance plant growth by providing targeted nutrient delivery, increasing bioavailability and promoting overall plant growth. These results were in closely related with the findings of Sukirtee et al. (2018) and Kumar et al. (2016).

Table 2 Effect of different nutrient management on plant height of Indian mustard.

Treatment		Plant height			
		30 DAS	**60 DAS**	**90 DAS**	**AT harvest**
T_1	Absolute control (No use of fertilizer and chemicals)	18.28	69.68	112.85	129.63
T_2	100% NPK and S+ Zn 5 Kg ha^{-1}	22.07	83.29	129.12	145.06
T_3	100% NPK and S+ Bio stimulants	22.39	85.37	131.09	145.94
T_4	100% NPK and S+ Nano Zn spray at 40 DAS	23.54	95.56	144.23	161.57
T_5	75% NKP and S+ NPK consortia	21.12	77.38	122.81	140.25
T_6	75% NPK and S+ Nano N spray at 40 DAS	21.61	79.47	126.72	143.52
T_7	75% NPK and S+ Nano N spray at 40 DAS + Nano Zn spray at 40 DAS	23.20	92.65	142.43	158.34
T_8	75% NPK and S+ NPK consortia + Nano Zn spray at 40 DAS	22.54	86.15	131.39	146.52
	SE(m)±	1.54	2.53	3.81	4.38
	C.D.	NS	7.76	11.67	13.40

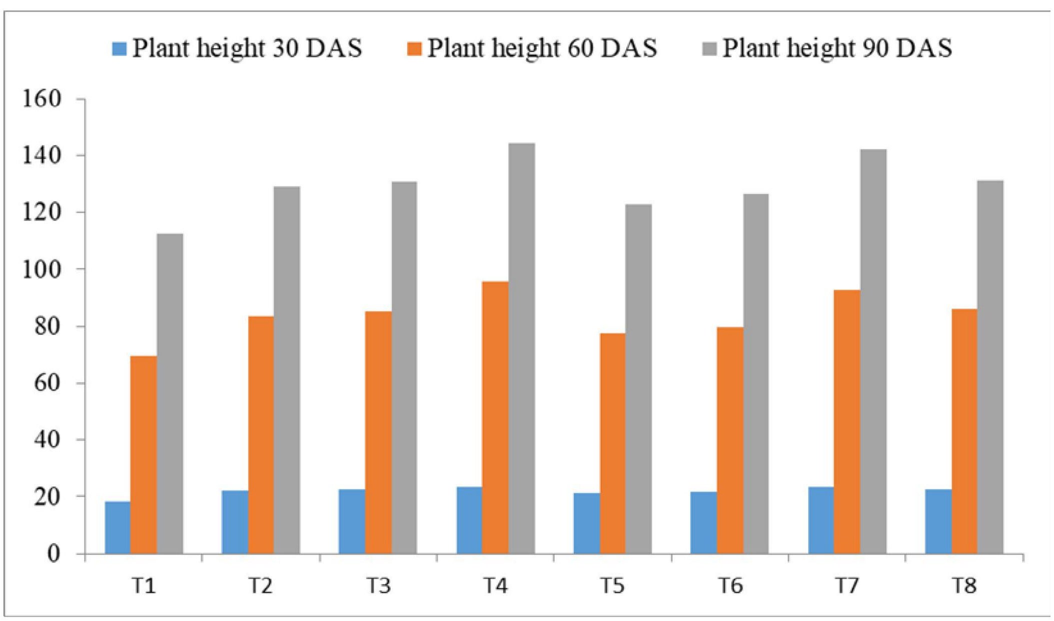

Fig. 1. Effect of different nutrient management on plant height of Indian mustard.

Dry matter accumulation (g m^{-2})

The integration of nitrogen and nano fertilizer significantly influenced the yield of the mustard crop regarding total dry matter accumulation. A noticeable increment was recorded at 60, 90 DAS and at harvest stage of mustard crop and is presented in Table 3 and Fig. 2. The effect of various treatments on dry matter accumulation of mustard crop was found non-significant at 30 DAS. As per the data observed at 60, 90 DAS and at harvest the highest buildup of dry matter (respectively) were achieved under treatment T_4 (100% NPK and S+ NANO Zn spray at 40 DAS). It was shown to be significantly on par with treatment T_7 (75% NPK and S+ Nano N spray at 40 DAS + Nano Zn spray at 40 DAS). Treatment T_1 (Absolute control) had the lowest dry matter accumulation of the mustard crop at 30, 60, 90 DAS and at harvest stage, respectively.

Nano material play important role in enhancing root growth of mustard crop which might have resulted in better nutrient uptake leading to efficient photosynthesis activity which ultimately results in more dry matter production in crop. This is line with findings of Khatkar et al. (2009). Metabolic activities inside the plant body affect dry matter accumulation. Better rhizospheric environment and more availability of nutrient at all the growth stages might have better metabolic activity and cellular activities (i.e. cell multiplication, cell elongation and cell expression) inside the plant system. This line was findings of Arora et al. (2012), Choudhary et al. (2021).

Table 3. Effect of different nutrient management on dry matter accumulation of Indian mustard.

Treatment		**Dry matter accumulation**			
		30 DAS	**60 DAS**	**90 DAS**	**AT harvest**
T_1	Absolute control (No use of fertilizer and chemicals)	8.56	14.74	36.97	52.82
T_2	100% NPK and S+ Zn 5 Kg ha^{-1}	11.04	23.39	47.84	75.28
T_3	100% NPK and S+ Bio stimulants	11.48	25.95	51.58	82.71
T_4	100% NPK and S+ Nano Zn spray at 40 DAS	12.56	31.02	60.72	99.73
T_5	75% NKP and S+ NPK consortia	9.39	18.93	40.29	61.62
T_6	75% NPK and S+ Nano N spray at 40 DAS	9.83	21.28	45.69	68.17
T_7	75% NPK and S+ Nano N spray at 40 DAS	12.37	29.14	59.39	94.72

	+ Nano Zn spray at 40 DAS				
T_8	75% NPK and S+ NPK consortia + Nano Zn spray at 40 DAS	11.76	26.18	54.48	86.81
	SE(m)±	1.77	0.73	1.50	2.28
	C.D.	NS	2.25	4.60	6.99

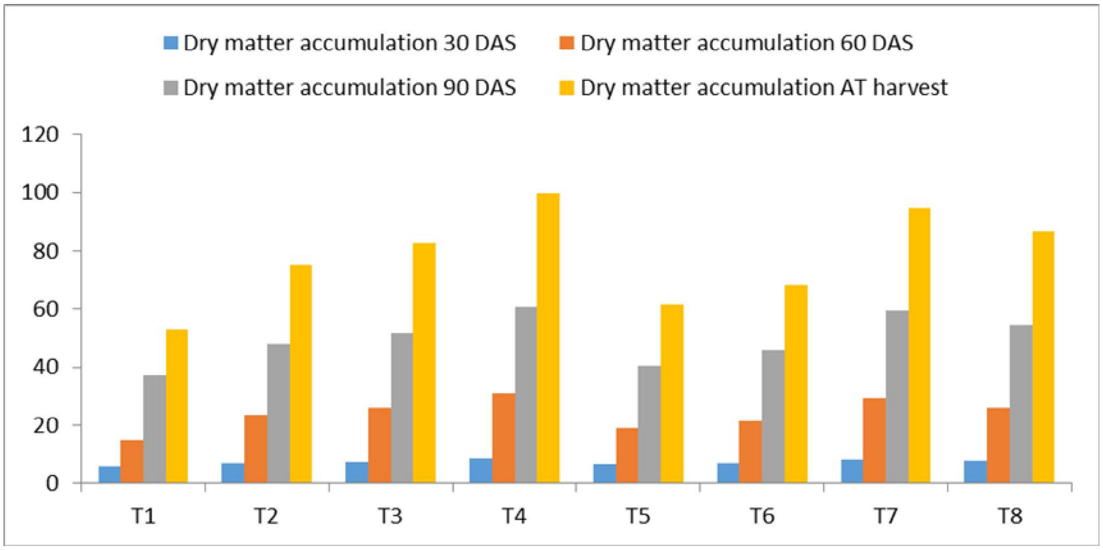

Fig. 2 Effect of different nutrient management on dry matter accumulation of Indian mustard

Yield attributes

The various treatments were considerable in increasing the yield attributes of mustard crop. The data regarding to yield attributes of mustard crop were presented in Table 4 and illustrated in Fig. 3.

Number of siliquae plant^{-1}

The treatment T_4 (100% NPK and S+ NANO Zn spray at 40 DAS) was found the highest number of siliquae plant^{-1} of mustard crop and it was statistically at par with treatment T_7 (75% NPK and S+ Nano N spray at 40 DAS + Nano Zn spray at 40 DAS) and superior over rest of the treatments. While, lowest number of siliquae plant^{-1} was recorded under treatment T_1 (Absolute control). Better nutrient availability might have resulted in production of more sinks leading to more accumulated dry matter production and more branches plant^{-1} which ultimately resulted in a greater number of siliquae plant^{-1} of mustard crop. Similar findings are also reported by Gangwar et al. (2011), kumar et al. (2014).

Siliquae length (cm)

The maximum siliquae length of mustard crop was observed under treatment T_4 (100% NPK and S+ NANO Zn spray at 40 DAS) which was significantly on par with treatment T_7 (75% NPK and S+ Nano N spray at 40 DAS + Nano Zn spray at 40 DAS). Whereas, T_1 (Absolute control) were noted the lowest siliquae length of mustard crop. Application of synthetic fertilizer along with sulphur and nano fertilizer are responsible for increasing the translocation of photosynthates towards sink resulted in increasing in siliquae length. These results are in conformity with the findings of Rathor et al. (2019), Kumar et al. (2020).

Number of seeds siliquae plant^{-1}

The various treatments were failed to show significant effects on number of seeds siliquae plant^{-1} of mustard crop. Whereas, the highest number of seeds siliquae plant^{-1} was noted under treatment T_4 (100% NPK and S+ NANO Zn spray at 40 DAS) and minimum number of seeds siliquae plant^{-1} was recorded under treatment T_1 (Absolute control)**.**

Test weight (g)

The effect of various treatments was also failed to create significant effects on test weight of mustard crop. However, the maximum test weight of mustard crop was observed under treatment T_4 (100% NPK and S+ NANO Zn spray at 40 DAS). While, minimum test weight was found under treatment T_1 (Absolute control)**.**

Weight of siliquae plant^{-1}

Application NPK and nano fertilizer were considerably increasing the weight of siliquae plant^{-1} of mustard crop during the field experiment. The highest weight of siliquae plant^{-1} was observed under treatment T_4 (100% NPK and S+ NANO Zn spray at 40 DAS) and it was statistically at par with treatment T_7 (75% NPK and S+ Nano N spray at 40 DAS + Nano Zn spray at 40 DAS). While, treatment T_1 (Absolute control) was recorded under the lowest weight of siliquae plant^{-1} of mustard crop. This might be due to the better absorption of nutrients resulted in more weight of siliquae plant^{-1}. Similar findings are also observed by Pandav et al. (2022), Rajput et al. (2018).

Table 4. Effect of different nutrient management on yield attributing character of Indian mustard.

Treatment		Number of siliquae plant^{-1}	Siliquae length (cm)	Number of seeds siliquae plant^{-1}	Test weight (g)	Weight of Siliquae plant^{-1}
T_1	Absolute control (No use of fertilizer and chemicals)	208.62	3.79	11.23	4.19	24.48
T_2	100% NPK and S+ Zn 5 Kg ha^{-1}	230.49	4.75	11.95	4.71	30.72
T_3	100% NPK and S+ Bio stimulants	238.73	4.96	12.06	4.76	33.96
T_4	100% NPK and S+ Nano Zn spray at 40 DAS	265.27	5.87	12.30	4.90	40.36
T_5	75% NKP and S+ NPK consortia	217.95	4.16	11.58	4.55	27.59
T_6	75% NPK and S+ Nano N spray at 40 DAS	222.83	4.54	11.73	4.63	29.38
T_7	75% NPK and S+ Nano N spray at 40 DAS + Nano Zn spray at 40 DAS	258.34	5.63	12.25	4.86	38.69
T_8	75% NPK and S+ NPK consortia + Nano Zn spray at 40 DAS	242.67	5.24	12.13	4.80	35.74
	SE(m)±	6.84	0.15	0.35	0.22	1.05
	C.D.	20.96	0.47	NS	NS	3.22

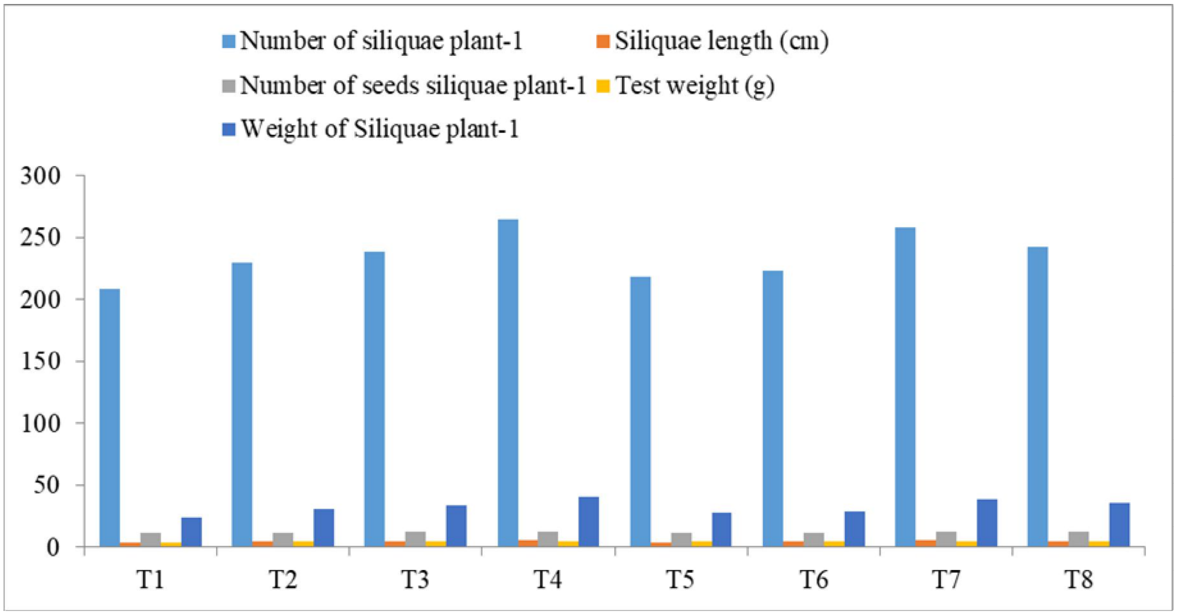

Fig. 3. Effect of different nutrient management on yield attributing character of Indian mustard.

Yields of mustard

The seed yield, stover yield, biological yield and harvest index of mustard crop is presented in Table 5 and illustrated in Fig. 4.

Seed yield (q ha^{-1})

The seed yield of mustard crop was varied significantly among the various treatment applications. Amongst various treatments T_4 (100% NPK and S+ NANO Zn spray at 40 DAS) was observed the maximum seed yield of mustard crop and it was statistically at par with treatment T_7 (75% NPK and S+ Nano N spray at 40 DAS + Nano Zn spray at 40 DAS) and superior of rest of the treatments. Whereas, the minimum seed yield of mustard crop was noted under treatment T_1 (Absolute control) during the field study. Treatment T_4 recorded the highest seed yield of mustard crop which might be due higher values of various growth parameters and yield character of mustard crop. Better translocation of photosynthates from source to sink has led to better growth parameters and higher yield attributing characters which might be resulted in maximum seed yield of mustard crop. These results are in conformity with the findings of Yadav and Dhanai (2016).

Stover yield (q ha^{-1})

Amongst various treatments application of NPK and nano fertilizer were considerably increase the stover yield of mustard crop during the field experiment. The highest stover yield of mustard crop was observed under treatment T_4 (100% NPK and S+ NANO Zn spray at 40 DAS) which was statistically on par with treatment T_7 (75% NPK and S+ Nano N spray at 40 DAS + Nano Zn spray at 40 DAS). However, treatment T_1 (Absolute control) was noted the lowest seed yield of mustard crop during field study. This might be due to the better availability of nutrients which resulted in higher stover yield leading to more accumulated dry matter of mustard crop. Similar findings are also noted by Gangwar et al. (2011), Verma et al. (2022).

Biological yield (q ha^{-1})

The maximum biological yield was found under treatment T_4 (100% NPK and S+ NANO Zn spray at 40 DAS) and it was statistically comparable with treatment T_7 (75% NPK and S+ Nano N spray at 40 DAS + Nano Zn spray at 40 DAS). While, the lowest seed yield of mustard crop was noted under treatment T_1 (Absolute control) during field experiment. Highest biological yield might could be attributed to combined effect of seed and stover yields of mustard crop. Better dry matter accumulation resulted in better translocation of photosynthates resulting in higher seed, stover and biological yield. These results are similar with the results of Kumar et al. (2022).

Harvest index (%)

The harvest index of mustard crop was found non-significant. However, the treatment T_4 (100% NPK and S+ NANO Zn spray at 40 DAS) was noted the highest harvest index of mustard crop and lowest harvest index was observed under treatment T_1 (Absolute control).

Table 5 Effect of different nutrient management on yield character of Indian mustard.

Treatment		Seed yield (q ha^{-1})	Stover yield (q ha^{-1})	Biological yield (q ha^{-1})	Harvest index (%)
T_1	Absolute control (No use of fertilizer and chemicals)	12.69	45.71	58.40	21.73
T_2	100% NPK and S+ Zn 5 Kg ha^{-1}	19.79	68.81	88.60	22.34
T_3	100% NPK and S+ Bio stimulants	21.39	77.29	98.68	21.68

T_4	100% NPK and S+ Nano Zn spray at 40 DAS	23.71	95.38	119.09	19.91
T_5	75% NKP and S+ NPK consortia	15.56	51.68	67.24	23.14
T_6	75% NPK and S+ Nano N spray at 40 DAS	16.49	58.59	75.08	21.96
T_7	75% NPK and S+ Nano N spray at 40 DAS + Nano Zn spray at 40 DAS	22.36	90.49	113.52	20.29
T_8	75% NPK and S+ NPK consortia + Nano Zn spray at 40 DAS	21.96	83.83	105.79	20.76
	SE(m)±	0.56	2.12	2.65	1.10
	C.D.	1.71	6.48	8.11	NS
	C.V.	5.02	5.13	5.05	8.88

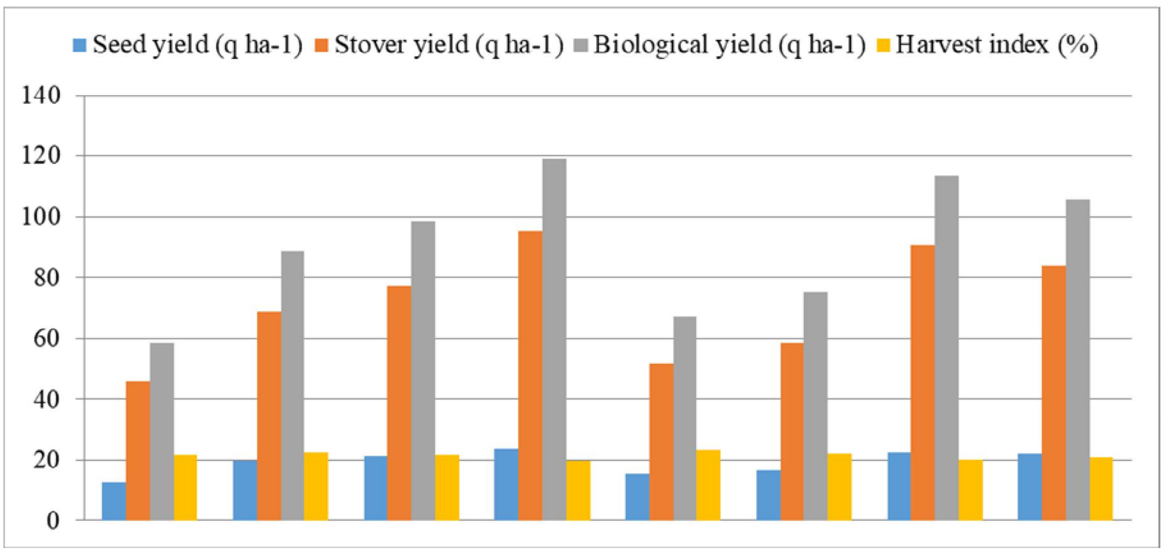

Fig. 4 Effect of different nutrient management on yield character of Indian mustard.

Conclusion:

As a result of the study's findings, the NPKS and Nano fertilizer exhibits the greatest growth outcomes when compared to other nano fertilizers. Applying nano fertilizers to accelerate plant development and output can potentially open new avenues in agricultural operations, since they appear to be a safe way to give plants nutrients without endangering the environment. More fieldwork is required to investigate the effects of this concentration on mustard crop growth and metabolism in order to guarantee the safety of the plants treated with nanoparticles for usage by people and animals.

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