



Optimization of Chemical Fertilizer through Integrated Nutrient Management (INM) Approach and its Effect on Growth and Yield of Mustard (*Brassica juncea* L.)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

A field experiment to test the optimization of chemical fertilizer use through Integrated Nutrient Management (INM) approach and its effect on growth and yield of Mustard (*Brassica juncea* L.) was carried out at Rampur agricultural field of Doon (P.G) College of Agriculture Science and Technology, Selaqui, Dehradun, Uttarakhand during the rabi season 2021-2022. The experiment comprised of nine treatments of organic and inorganic nutrient combination, viz T1- Control (No

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Fertilizer), T2- Recommended Dose of Fertilizer (RDF) (80:60:40 kg/ha), T3- 100 % vermicompost (6.0 t/ha), T4- 75% Farm Yard Manure (FYM) (15.0 t/ha) + 25% RDF (20:15:10 kg/ha), T5- 50% RDF (40:30:20 kg/ha) + FYM (5.0 t/ha) + green manure (2.5 t/ha) + gypsum (10.0 kg/ha), T6-50% RDF (40:30:20 kg/ha) + vermicompost (3.0 t/ha)+ gypsum (5.0 kg/ha), T7- 75% RDF (60:45:30 kg/ha) + vermicompost (2.5 t/ha), T8- 75% RDF (60:45:30 kg/ha) + vermicompost (1.5 t/ha) + green manure (1.5 t/ha), T9- 75% RDF (60:45:30 kg/ha) + FYM (1.5 t/ha) + vermicompost (1.0 t/ha) + green manure (1 t/ha) + gypsum (10.0 kg/ha), laid out in randomized block design with three replication. The results of experiment revealed that there was increase in plant growth parameters in the treatment T9, followed by treatment T8 and T5, respectively. Moreover, the maximum seed yield (2240.39 kg/ha) was observed under T9 over control, where no fertilizer application was applied. The present investigation established the fact that integrated use both organic and inorganic fertilizer can be recommended to the farmers as one of the key strategies for enhancing crop response in terms of growth and yield of mustard.

Keywords: Integrated nutrient management; oil seeds; organic manures; norganic nutrients.

1. INTRODUCTION

Mustard (*Brassica juncea* (L.)) is considered to be one of the most valuable oil-seed crops. It belongs to *Brassicaceae* (*Cruciferae*) family, with around 338 genera and 3709 species scattered worldwide. Mustard seeds are known by several names in different parts of the world, such as sarson, rai or raya, toria or lahi. While sarson and toria (lahi) are commonly referred to as rapeseed, rai, raya, or laha. Afghanistan and neighbouring countries (Central Asia) were the principal sites of origin, whereas central and western China, eastern India, and Asia were subsidiary centres of origin for Brassica [1].

China is the first largest producer of rapeseed mustard followed by Canada. India is the third largest producer of rapeseed-mustard and contributes to around 11% of the world's total production [2]. Mustard production has raised by 40% from 91.24 to 128.18 lakh tonnes during last 3 years. The productivity saw 11% increase from 1331 to 1447 kg/ha. The area under rapeseed and mustard enhanced by 29% from 68.56 lakh ha in 2019-20 to 88.58 lakh ha in 2022-23. Timely action by central and state government made this remarkable achievement possible [3].

In India, mustard is grown in Rajasthan, Madhya Pradesh, Uttar Pradesh, Uttarakhand, Haryana, Gujarat, Andra Pradesh, Karnataka, and Tamil Nadu. Yellow sarson is grown as a rabi crop in Assam, Bihar, Orissa, and West Bengal, but as a catch crop in Punjab, Haryana, Uttar Pradesh, and Himachal Pradesh. Previously, brown sarson was planted in the majority of the areas; however, its area under cultivation is decreasing and being replaced by Indian mustard. Shekhawat *et al.*, [4].

India is a major importer of edible oils since domestic supply cannot fulfil domestic demand. Imports supply around 56-60% of the edible oils consumed in the nation. Madhya Pradesh comes out on top in total oilseeds output (31%), followed by Rajasthan and Gujarat. The mustard crop is widely grown in northern India. Rajasthan has 46.06 percent mustard farming, followed by Haryana (12.60 percent), Madhya Pradesh (11.38 percent), Uttar Pradesh (10.49 percent), and West Bengal (7.81 percent) [5].

Mustard is high in nutrients and its oil content ranges from 25 to 49 percent. Mustard greens are high in Vitamin A, Vitamin B6, Vitamin C, Vitamin E, and beta-carotene. It is mostly composed of folate, oleic, erucic, and linoleic fatty acids (Campbell *et al.*, [6] Jaiswal *et al.*, [7] Tian and Deng, 2020).

Consistent application of fertilizers and other chemicals adversely affects soil health in terms of sustainability and productivity. Rapeseed and mustard are the nutrient demanding crops that require significant energy, necessitate careful fertilizer management for optimal growth (Sharma, 1986). Inadequate fertilization, specifically sub-optimal doses, leads to reduced yields in farmers' fields. It is crucial to assess the growth characteristics and harness their production potential across varying fertilizer levels. By combining inorganic fertilizers with organic manures and bio-fertilizers, the crop productivity can be sustained as well as soil health can be improved, and nutrient-use efficiency can be accelerated, as emphasized by Kakraliya *et al.*, [8].

For the growth and development of plants, nitrogen (N) is a critical metabolic component. A

strong root system can only develop when phosphorus (P) is present. Potassium (K) significantly raises grain and stover yield. The fundamental elements of plant life also require other nutrients. Ye *et al.*, [9] Chen *et al.*, [10]. The core strategy for optimizing nutrient supply to plants and preserving soil nutrient stocks, thereby enhancing soil health and crop production, lies in the integrated nutrient management approach. This approach is based on the premise that chemical fertilizers can be efficiently delivered to plants while simultaneously improving the biological environment of the soil. Different research findings revealed that adoption of integrated nutrient management practices, reduced emissions of greenhouse gases and reactive nitrogen losses are decreased. Lower inputs of fertilizers (chemical), lower environmental as well as human costs were achieved because of INM methods [11]. Keeping in view the above facts, the investigation was carried out to see the effect of integrated Nutrient Management (INM) on growth and yield of Mustard (*Brassica juncea* L.)

2. MATERIALS AND METHODS

The field experiment was conducted during rabi season 2021-2022 at Rampur experimental farm, Department of Agronomy, Doon (P.G) College of Agriculture Science and Technology, Dehradun, Uttarakhand. The experimental site is situated at a Latitude 30.369117° and Longitude 77.839441° with minimum and maximum temperatures ranging from 8.1 °C to 24.9 °C (at sowing) and 14.4 °C to 34.7 °C, (at harvest) respectively. The mean relative humidity ranged from 50.8 percent

(evening) to 95.5 percent (morning). Before the initiation of the experiment, the composite soil sample was collected at a depth of 0-15 cm for analysis of Physico-chemical parameters of soil. The details of soil properties are presented in Table 1.

2.1 Physical Properties

The soil of experimental field was sandy loam in texture having a pH of 7.59, EC 0.39 dSm⁻¹ and having a low soil organic carbon (0.38%). The experimental soil contained 228.6, 36.34, 192.0 and 15.64 kg ha⁻¹ of N, P, K and S, respectively. The experiment was conducted in randomized block design (RBD) having three replications. The mustard cultivar used during this study was DRMR 1165-40. It was sown under different doses of nutrient or fertilizer regime viz. T₁- Control (No Fertilizer), T₂- General Recommended Dose (80:60:40 kg/ha), T₃- 100% vermicompost (6.0 t/ha), T₄- 75% F.Y.M (15.0 t/ha) + 25% R.D.F (20:15:10 kg/ha), T₅- 50% R.D.F (40:30:20 kg/ha) + F.Y.M (5.0 t/ha) + green manure (2.5 t/ha) + gypsum (10.0 kg/ha), T₆-50% R.D.F (40:30:20 kg/ha) + vermicompost (3.0 t/ha)+ gypsum (5.0 kg/ha), T₇- 75% R.D.F (60:45:30 kg/ha) + vermicompost (2.5 t/ha), T₈- 75% R.D.F (60:45:30 kg/ha) + vermicompost (1.5 t/ha) + green manure (1.5 t/ha), T₉- 75% R.D.F (60:45:30 kg/ha) + F.Y.M (1.5 t/ha) + vermicompost (1.0 t/ha) + green manure (1 t/ha) + gypsum (10.0 kg/ha). The source of nutrient used for nitrogen, phosphorus and potassium were urea, SSP (single super phosphate) and MOP (muriate of potash),

Table 1. Soil physico-chemical properties of the experimental site

Properties	Values	Methods employed
Sand (%)	58.69	Bouycos Hydrometer method
Silt (%)	27.76	Black, [12]
Clay (%)	13.55	
Texture class	Sandy-loam	USDA Textural Triangle
Soil pH (1:2.5)	7.59	Glass electrode digital meter. (Jackson 1973)
Electrical conductivity (dS m ⁻¹) at 25°C (1:2.5)	0.39	EC meter Bower and Wilcox [13]
Organic carbon (%)	0.38	Walkley and Black's rapid titration method (1965)
Available Nitrogen (kg/ha)	228.6	Alkaline permanganate method Subbiah and Asija, [14]
Available Phosphorus(kg P ₂ O ₅ /ha)	36.34	Olsen's extraction method Olsen <i>et al.</i> , [15]
Available Potassium (kg K ₂ O /ha)	192.0	Neutral 1 N NH ₄ OAc extraction method Hanway and Hiedel, [16]

respectively. The observations were recorded from five randomly selected plants from each plot in each replication.

2.2 Statistical Analysis

All data related to pre- and post-harvest study of the crop were collected and statistically analyzed by using the analysis of variance technique (ANOVA) (Fisher, 1958). Data so computed was subjected to Fisher's analysis of variance for judging the effect of various treatments. The statistical analysis was carried out by OPSTAT-HAU and STPR3.

3. RESULTS AND DISCUSSION

3.1 Growth Parameters

3.1.1 Plant Height (cm)

Data pertaining to plant height of mustard at 25, 45, 75, 100 DAS is depicted in Table 2. It was observed that different nutrient combinations showed significant effect on plant height at 25 DAS. However, maximum (14.69 cm) plant height at 25 DAS was observed under T₉ (75% R.D.F (60:45:30 kg/ha) + F.Y.M @1.5 t/ha + vermicompost @1 t/ha + G.M @1 t/ha + Gypsum @10 kg/ha) followed by T₈ (75% R.D.F (60:45:30 kg/ha) + vermicompost @1.5 t/ha + G.M @1.5 t/ha) and T₇ (75% R.D.F (60:45:30 kg/ha) + vermicompost @ 2.5 t/ha), respectively.

Further maximum plant height (22.96, 110.59 and 158.63 cm) was reported under treatment T₉, and lowest plant height was observed at T₄ (75% F.Y.M (15t/ha) +25% R.D.F (20:15:10 kg/ha)) and ultimate lowest (15.23, 86.95 and 112.41) cm was reported under treatment T₁ (Control) at 45, 75 and 100 DAS, respectively.

The combination use of chemical fertilizers and organic manure, which met the crop's immediate nutrient needs and improved soil conditions, may have contributed to the observed positive outcomes, similar findings were reported by Tripathi et al. [17]. This could be attributed to the use of organic fertilizers containing Bio-NPK, which resulted in increased photosynthetic activity, chlorophyll formation, nutrient metabolism, and hormonal content in the plants. This, in turn, elevated metabolic activity by supplying essential macro and micronutrients. Similar outcomes were observed in

studies conducted by Jethava et al. [18], Kumar et al. [19], Parmar et al. [20] and Singh et al. [21] and Kumar et al. [22] and Waskel et al. [23].

3.1.2 Number of leaves per plant

Table 2 contains data regarding the number of mustard plant leaves observed at 25, 45, 75, and 100 DAS. At 25 DAS, plant leaves varying in size from 4.48 cm to 5.86 cm were seen to be significantly affected by a variety of treatments. However, maximum (5.86 cm) plant leaf at 25 DAS was observed under T₉, where 75% R.D.F (60:45:30 kg/ha) along with F.Y.M (1.5 t/ha) + vermicompost (1.0 t/ha) + green manure (1 t/ha) + gypsum (10 kg/ha) followed by T₂ i.e., R.D.F (80:60:40 kg/ha), T₃ i.e., 100 % Vermicompost (6 t/ha), T₅ i.e., 50% R.D.F (40:30:20 kg/ha) + F.Y.M (5 t/ha) + Green Manure (2.5 t/ha) + Gypsum (10.0 kg/ha), T₆ i.e., 50% R.D.F (40:30:20 kg/ha) + vermicompost (3.0 t/ha) + gypsum (5.0 kg/ha), T₈ i.e., 75% R.D.F (60:45:30 kg/ha) + vermicompost (1.5 t/ha) + green manure (1.5 t/ha) and T₇ i.e., 75% R.D.F (60:45:30 kg/ha) + vermicompost (2.5 t/ha) respectively and these treatments were found to be significantly at par with T₉ i.e., 75% R.D.F (60:45:30 kg/ha) + F.Y.M (1.5 t/ha) + vermicompost (1.0 t/ha) + green manure (1.0 t/ha) + gypsum (10.0 kg/ha). However, very less number of plant leaves was observed at T₃ and lowest in T₁ (Control) where no fertilizer application was done.

Further maximum plant leaves (7.62, 21.11 and 16.60) cm was reported under treatment T₉, and lowest plant leaves at T₃, T₇ and T₂ and ultimate lowest (5.96, 14.50 and 8.27) cm was reported under treatment T₁ at 45, 75 and 100 DAS, respectively.

Application of N directly influences the vegetative growth of the plant. FYM improves the soil's physio-chemical condition, creating a favourable environment which promotes the absorption of nutrients and boosts macro as well as micronutrients uptake which eventually enhances the overall growth of the plants. Similar results were found by Jeet et al. (2012) who reported that increasing nitrogen availability in the soil through the use of FYM improved the number of leaves per plant in rapeseed.

Table 2. Plant height (cm) and number of leaves of mustard as influenced by different uses of fertilizer

Treatments	Plant height (cm)				Number of Leaves			
	25 DAS	45 DAS	75 DAS	100 DAS	25 DAS	45 DAS	75 DAS	100 DAS
T ₁ Control (No Fertilizer)	8.82	15.23	86.95	112.41	4.48	5.96	14.50	8.27
T ₂ Recommended Dose of Fertilizer (80:60:40 kg/ha)	11.76	19.89	109.81	122.73	5.47	7.03	19.31	10.73
T ₃ 100 % vermicompost (6.0 t/ha)	12.36	20.69	97.00	129.53	5.17	6.15	19.84	11.50
T ₄ 75% F.Y.M (15.0 t/ha) +25% R.D.F (20:15:10 kg/ha)	9.56	16.56	101.75	127.04	4.68	7.03	19.01	11.93
T ₅ 50% R.D.F (40:30:20 kg/ha) + F.Y.M (5.0 t/ha) + green manure (2.5 t/ha) + gypsum (10.0 kg/ha)	11.09	21.69	95.67	141.98	5.27	7.23	19.84	12.87
T ₆ 50% R.D.F(40:30:20 kg/ha) + vermicompost (3t/ha)+ gypsum (5 kg/ha)	10.76	18.49	96.78	138.58	5.76	6.93	19.46	11.47
T ₇ 75% R.D.F (60:45:30 kg/ha) + vermicompost (2.5 t/ha)	13.69	21.16	88.38	129.57	5.17	6.64	18.26	12.87
T ₈ 75% R.D.F (60:45:30 kg/ha) + vermicompost (1.5 t/ha) + green manure (1.5 t/ha)	13.76	21.76	97.66	141.43	5.27	7.42	19.08	12.07
T ₉ 75% R.D.F (60:45:30 kg/ha) + F.Y.M (1.5 t/ha) + vermicompost (1.0 t/ha) + green manure (1.0 t/ha)+ gypsum (10.0 kg/ha)	14.69	22.96	110.59	158.63	5.86	7.62	21.11	16.60
Sem ±	0.67	1.35	5.01	7.76	0.26	0.32	1.11	0.48
CD (P= 0.05)	2.00	4.05	15.02	23.25	0.78	0.96	3.33	1.45

3.1.3 Number of branches per plant

Data pertaining to number of branches per plant were recorded at 45, 75 and 100 DAS and presented in Table. 3.. It can be observed that various treatments showed significant effect on number of plant branches at 45 DAS varied from 1.80 to 3.60. However , maximum (3.60) plant branches at 45 DAS was observed under T₉ , where 75% R.D.F (60:45:30 kg/ha) along with F.Y.M (1.5 t/ha) + vermicompost (1.0 t/ha) + green manure (1.0 t/ha) + gypsum (10.0 kg/ha) followed by T₈ i.e., 75% R.D.F (60:45:30 kg/ha) + vermicompost (1.5 t/ha) + green manure (1.5 t/ha) and T₇ i.e., 75% R.D.F (60:45:30 kg/ha) + vermicompost (2.5 t/ha) respectively and these treatments were found to be significantly at par with T₉ i.e., 75% R.D.F (60:45:30 kg/ha) + F.Y.M (1.5 t/ha) + vermicompost (1.0 t/ha) + green manure (1.0 t/ha) + gypsum (10.0 kg/ha) . However, the lowest plant height was observed at T₂ and ultimate lowest in T₁

(Control) where no fertilizer application was done.

Further maximum number of plant branches (7.53 and 7.73) were reported under treatment T₉, where 75% R.D.F (60:45:30 kg/ha) along with F.Y.M (1.5 t/ha) + vermicompost (1.0 t/ha) + green manure (1.0 t/ha) + gypsum (10.0 kg/ha) and lowest plant branches at T₄, T₂ and ultimate lowest (3.79 and 3.89) was reported under treatment T₁ (Control) at 75 and 100 DAS, respectively.

The combination use of chemical fertilizers and organic manure, which met the crop's immediate nutrient needs and improved soil conditions, may have contributed to the observed positive outcomes. A similar result was given by Kalita et al. [24]. Improving soil fertility using Inorganic and organic fertilizer may have contributed to the enhanced plant growth seen in the present study.

3.1.4 Dry matter accumulation per plant (gm)

Dry matter accumulation per plant (gm) of mustard is influenced by different uses of fertilizer. It can be observed that various treatments showed significant effect on plant dry matter weight at 25 DAS, varied from 1.38 to 2.23 gm. However, maximum (2.23 gm) dry weight at 25 DAS was observed under T₉, where 75% R.D.F (60:45:30 kg/ha) along with F.Y.M (1.5 t/ha) + vermicompost (1.0 t/ha) + green manure (1.0 t/ha) + gypsum (10.0 kg/ha). However less dry matter accumulation was observed at T₂ and lowest was observed in T₁ (Control) where no fertilizer application was done.

Plant dry matter at 45 DAS varied from 13.85 to 17.90 gm during the study. However, maximum (17.90 gm) plant dry matter at 45 DAS was observed under T₉, followed by T₅, T₆ and T₇ respectively and these treatments were found to be significantly at par with T₉ i.e., 75% R.D.F (60:45:30 kg/ha) + F.Y.M (1.5 t/ha) + vermicompost (1.0 t/ha) + green manure (1.0

t/ha) + gypsum (10.0 kg/ha). However, very less plant dry matter was found under T₂ treatment and ultimate lowest observed in T₁ (Control) where no fertilizer applied.

Further maximum amount plant dry matter (43.64 and 85.20) was reported under treatment T₉, and lowest plant dry matter observed at T₄ and least (35.59 and 64.64) was reported under treatment T₁ at 75 and 100 DAS, respectively.

When organic manures are combined with inorganic fertilisers and incorporated into soil, they boost root growth, thereby increasing the total surface area of the roots that can absorb water. Taller plants have more possibilities to make and store photosynthates, therefore they produce more dry matter, which leads to increased dry weight. It was also discovered that the use of chemical fertilisers in conjunction with FYM, Zn and seed treatment had a good effect on the height and dry matter content of mustard plants [25,17].

Table 3. Number of branches and dry matter accumulation plant⁻¹ of mustard as influenced by different uses of fertilizer

Treatments	Number of branches			Dry matter accumulation			
	45 DAS	75 DAS	100 DAS	25 DAS	45 DAS	75 DAS	100 DAS
T ₁ Control (No Fertilizer)	1.80	3.79	3.89	1.38	13.85	35.59	64.64
T ₂ Recommended Dose of Fertilizer (80:60:40 kg/ha)	2.40	5.36	5.39	1.58	14.80	38.10	69.01
T ₃ 100 % vermicompost (6.0 t/ha)	2.50	6.06	6.66	1.72	14.85	38.28	68.65
T ₄ 75% F.Y.M (15 t/ha) + 25% R.D.F (20:15:10 kg/ha)	2.60	4.99	5.46	1.75	14.90	37.99	67.58
T ₅ 50% R.D.F (40:30:20 kg/ha) + F.Y.M (5.0 t/ha) + green manure (2.5 t/ha) + gypsum (10.0 kg/ha)	3.20	6.59	6.79	1.78	17.55	41.44	82.24
T ₆ 50% R.D.F (40:30:20 kg/ha) + vermicompost (3.0 t/ha) + gypsum (5.0 kg/ha)	3.00	6.39	6.79	1.77	16.25	39.39	74.09
T ₇ 75% R.D.F (60:45:30 kg/ha) + vermicompost (2.5 t/ha)	3.07	6.33	6.79	1.58	16.45	42.51	75.16
T ₈ 75% R.D.F (60:45:30 kg/ha) + vermicompost (2.5 t/ha) + green manure (2.5 t/ha)	3.13	6.39	6.79	1.92	17.15	43.63	82.36
T ₉ 75% R.D.F (60:45:30 kg/ha) + F.Y.M (2.5 t/ha) + vermicompost (2.0 t/ha) + green manure (2.0 t/ha) + gypsum (10.0 kg/ha)	3.60	7.53	7.73	2.23	17.90	43.64	85.20
Sem ±	0.20	0.31	0.31	0.13	0.81	1.75	3.45
CD (P= 0.05)	0.60	0.94	0.92	0.38	2.42	5.25	10.33

3.2 Yield Contributing Characters

3.2.1 Number of siliqua per plant

Table 4 contains information on the number of mustard siliqua per plants at 75 and 100 DAS. It can be observed that various treatments showed significant effect on number of siliqua per plant at 75 DAS varied from 17.40 to 26.30. However, maximum (26.30) number of siliqua per plant at 75 DAS was observed under T₉, where 75% R.D.F (60:45:30 kg/ha) along with F.Y.M (1.5 t/ha) + vermicompost (1.0 t/ha) + green manure (1.0 t/ha) + gypsum (10.0 kg/ha) followed by T₈ i.e., 75% R.D.F (60:45:30 kg/ha) + vermicompost (1.5 t/ha) + green manure (1.5 t/ha) and T₅ i.e., 50% R.D.F (40:30:20 kg/ha) + F.Y.M (5.0 t/ha) + green manure (2.5 t/ha) + Gypsum (10.0 kg/ha) respectively and these treatments were found to be significantly at par with T₉ i.e., 75% R.D.F (60:45:30 kg/ha) + F.Y.M (1.5 t/ha) + vermicompost (1.0 t/ha) + green manure (1.0 t/ha) + gypsum (10.0 kg/ha). However, the lowest number of siliqua per plant was observed at T₃ and ultimate lowest in T₁ (Control) where no fertilizer application was done.

Further maximum number of siliqua per plant (107.78) was reported under treatment T₉, and

lowest plant (46.88) was reported at T₃ and ultimate lowest under treatment T₁ at 100 DAS, respectively followed by T₈.

FYM application with chemical fertilisers and organic fertilizer improved mustard's growth characteristics, yield components, and final yield. All improved as a result of enhanced delivery of key nutrients. These results are in line with what was observed by Tripathi *et al.* [17].

3.2.2 Length of siliqua

Data recorded for length of siliqua of mustard is shown in Table 4. It can be observed that various treatments showed significant effect of length of siliqua varied from 5.81 to 6.59. However, maximum (6.59) length of siliqua was observed under T₉ followed by T₃, and T₂. However, the length of siliqua was very low observed in T₄ and lowest in T₁ (Control) where no fertilizer application was done. Nitrogen and phosphorus fertilizers increased glucose, protein, and reproductive organ accumulation, which boosted mustard yield. Organic fertilizers supplemented mustard higher nitrogen and phosphorus needs and gave a physiological benefit by creating phytohormones that improved yield.

Table 4. Number of siliqua plant⁻¹, Seed siliqua⁻¹, Siliqua length, Test weight of mustard as influenced by different uses of fertilizer

Treatments	Number of siliqua plant ⁻¹		Siliqua Length (cm)	No of seed siliqua ⁻¹	Test weight (gm)
	75 DAS	100 DAS			
T ₁ Control (No Fertilizer)	17.40	46.88	5.34	10.16	4.00
T ₂ Recommended Dose of Fertilizer (80:60:40 kg/ha)	19.57	85.28	6.41	10.66	4.20
T ₃ 100 % Vermicompost (6 t/ha)	18.40	78.81	6.48	11.99	4.30
T ₄ 75% F.Y.M (15 t/ha) + 25% R.D.F (20:15:10 kg/ha)	19.20	79.28	5.84	11.99	4.46
T ₅ 50% R.D.F (40:30:20 kg/ha) + F.Y.M (5t/ha) + Green Manure (2.5 t/ha) + Gypsum (10 kg/ha)	22.40	93.31	5.97	14.32	5.46
T ₆ 50% R.D.F (40:30:20 kg/ha) + vermicompost (3 t/ha) + Gypsum (5 kg/ha)	19.10	80.65	5.81	11.66	4.70
T ₇ 75% R.D.F (60:45:30 kg/ha) + vermicompost (2.5t/ha)	21.33	82.81	5.81	13.66	5.00
T ₈ 75% R.D.F (60:45:30 kg/ha) + vermicompost (1.5t/ha) + G.M (1.5 t/ha)	23.47	97.81	5.78	14.32	5.30
T ₉ 75% R.D.F (60:45:30 kg/ha) + F.Y.M (1.5 t/ha) + vermicompost (1 t/ha) + G.M (1 t/ha) + Gypsum (10 kg/ha)	26.30	107.78	6.59	14.99	5.86
Sem ±	1.33	4.81	0.25	0.59	0.25
CD (P= 0.05)	3.98	14.42	0.75	1.77	0.74

3.2.3 Number of seed per siliqua

Table 4 contains information on the number of mustard seed per siliqua. It can be observed that various treatments showed significant effect on number of seed per siliqua at harvest varied from 10.16 to 14.99. However, maximum (14.99) number of seed per siliqua at harvest was observed under T₉, where 75% R.D.F (60:45:30 kg/ha) along with F.Y.M (1.5 t/ha) + vermicompost (1.0 t/ha) + green manure (1.0 t/ha) + gypsum (10.0 kg/ha) followed by T₇ i.e., 75% R.D.F (60:45:30 kg/ha) + vermicompost (2.5 t/ha), T₈ i.e., 75% R.D.F (60:45:30 kg/ha) + vermicompost (1.5 t/ha) + green manure (1.5 t/ha) and T₅ i.e., 50% R.D.F (40:30:20 kg/ha) + F.Y.M (5.0 t/ha) + green manure (2.5 t/ha) + gypsum (10.0 kg/ha) respectively and these treatments were found to be significantly at par with T₉ i.e., 75% R.D.F (60:45:30 kg/ha) + F.Y.M (1.5 t/ha) + vermicompost (1.0 t/ha) + green manure (1.0 t/ha) + gypsum (10.0 kg/ha). However, very less number of seed per siliqua was observed in T₂ and ultimate lowest in T₁ (Control) where no fertilizer was used.

The quantity of seeds per siliqua increased can be attributed to the fact that the treatments improved cell division and tissue development. Increased seeds per siliqua also increased due to higher growth and more photosynthesis as a result of enough nutrients in the crop. Similar findings were reported by Mandal and Sinha [26].

3.2.4 Test weight (1000 seed weight)

Data recorded for test weight (1000 seed weight) of mustard at harvest in Table 4. It can be observed that various treatments showed significant effect on test weight (1000 seed weight) varied from 4.00 to 5.86 gm. However, maximum (5.86 gm) test weight was observed under T₉, where 75% R.D.F (60:45:30 kg/ha) along with F.Y.M (2.5 t/ha) + vermicompost (2.0 t/ha) + green manure (2.0 t/ha) + gypsum (10.0 kg/ha) followed by T₈ i.e., 75% R.D.F (60:45:30 kg/ha) + vermicompost (1.5 t/ha) + green manure (1.5 t/ha) and T₅ i.e., 50% R.D.F (40:30:20 kg/ha) + vermicompost (3.0 t/ha) + gypsum (5.0 kg/ha) respectively and these treatments were found to be significantly at par with T₉. However, very less test weight was observed at T₂ and ultimate lowest in T₁ (Control) where no fertilizer application was done. The findings were in close proximity with the investigation of Parmar et al. 2019 and Singh et al [21].

3.3 Yield

3.3.1 Seed yield (kg/ha)

Data recorded for seed yield (kg/ha) of mustard at harvest is there in Table 4. It can be observed that various treatments showed significant effect on seed yield (kg/ha) varied from 822.05 to 2240.39 kg/ha. However, maximum (2240.39 kg/ha) seed yield was observed under T₉, where 75% R.D.F (60:45:30 kg/ha) along with F.Y.M (1.5 t/ha) + vermicompost (1.0 t/ha) + green manure (1.0 t/ha) + gypsum (10.0 kg/ha). However, the lowest seed yield was observed at T₁ (Control) then followed by T₂.

The highest seed production was attained as a result of the combined effects of FYM, chemical fertilisers, and organic fertilisers. Over time, more effective uptake takes place and there is less nitrogen loss since FYM releases its nutrients gradually. Plant height, primary and secondary branches, siliqua quantity, siliqua length, seeds per siliqua, and seed weight were among the growth and yield characteristics that improved with improved nutrient utilisation. Similar trends in results were reported by the investigation of Chauhan et al. [27] Mukherjee et al. [28] and Thaneshwar et al. [29].

3.3.2 Stover yield (kg/ha)

Data was recorded for stover yield (kg/ha) of mustard at harvest presented in Table.4. It could be observed that various treatments showed significant effect on stover yield (kg/ha) and range varied from 3534.62 to 4899.78 kg/ha. However, maximum (4899.78 kg/ha) stover yield was observed under T₉, where 75% R.D.F (60:45:30 kg/ha) along with F.Y.M (1.5 t/ha) + vermicompost (1.0 t/ha) + green manure (1.0 t/ha) + Gypsum (10 kg/ha) followed by T₇ i.e., 75% R.D.F (60:45:30 kg/ha) + vermicompost (2.5 t/ha), T₈ i.e., 75% R.D.F (60:45:30 kg/ha) + vermicompost (1.5 t/ha) + G.M (1.5 t/ha) and T₂ i.e., recommended Dose of Fertilizer (80:60:40 kg/ha) respectively and these treatments were found to be significantly at par with T₉. However, the low stover yield was observed at T₄ and lowest in T₁ (Control) where no fertilizer application was done. This could be attributed to an augmented provision of essential plant nutrients, particularly nitrogen, which accelerates both the growth and reproductive phases. Additionally, the increased nutrient supply facilitates protein synthesis, ultimately promoting the yield of mustard.

Table 5. Seed yield, Stover yield (kg/ha) of mustard as influenced by different uses of fertilizer

Treatments	Seed yield (kg/ha)	Stover yield (kg/ha)	Harvest Index (%)
T ₁ Control (No Fertilizer)	822.05	3534.62	18.88
T ₂ Recommended Dose of Fertilizer (80:60:40 kg/ha)	1546.38	4331.59	26.36
T ₃ 100 % Vermicompost (6.0 t/ha)	1650.72	4035.23	29.03
T ₄ 75% F.Y.M (15.0 t/ha) + 25% R.D.F (20:15:10 kg/ha)	1634.72	3973.57	29.08
T ₅ 50% R.D.F (40:30:20 kg/ha) + F.Y.M (5.0 t/ha) + green manure (2.5 t/ha) + gypsum (10.0 kg/ha)	1820.72	4230.93	30.14
T ₆ 50% R.D.F (40:30:20 kg/ha) + vermicompost (3.0 t/ha) + gypsum (5.0 kg/ha)	1738.38	4236.76	28.96
T ₇ 75% R.D.F (60:45:30 kg/ha) + vermicompost (2.5 t/ha)	1809.72	4483.11	28.68
T ₈ 75% R.D.F (60:45:30 kg/ha) + vermicompost (1.5 t/ha) + green manure (1.5 t/ha)	1891.05	4635.05	28.90
T ₉ 75% R.D.F (60:45:30 kg/ha) + F.Y.M (1.5 t/ha) + vermicompost (1.0 t/ha) + green manure (1.0 t/ha) + gypsum (10 kg/ha)	2240.39	4899.78	31.49
Sem ±	110.84	199.45	1.42
CD (P= 0.05)	332.30	597.96	NS

Higher fertility enhanced plant height, leaf area and dry matter per plant, which boosted stover output and it was in accordance with Singh and Pal [25]. When nitrogen was increased by fertilizer N alone or in conjunction with organic fertilizers, yield characteristics and yield increased more than growth parameters. Which eventually lead to higher stover yield. Similar findings were done by Das, et al. [30] and Saha et al. [31].

3.4 Harvest Index (%)

Data of harvest index (%) was recorded at the time of harvest in Table 4. It was observed that various treatments showed significant effect on harvest index (%) varied from 18.88% to 31.49 %. However, maximum (31.49%) harvest index was observed under T₉, where 75% R.D.F (60:45:30 kg/ha) along with F.Y.M (1.5 t/ha) + vermicompost (1.0 t/ha) + green manure (1.0 t/ha) + Gypsum (10 kg/ha) followed by T₅. Very low harvest index was observed in T₂ and lowest was T₁ (Control) where no fertilizer application was done [32,33].

4. CONCLUSION

In every experiment treatment 9th showed magnificent result, so we could finally conclude that application of 75% R.D.F (60:45:30 kg/ha) +

F.Y.M (1.5 t/ha) + vermicompost (1.0 t/ha) + green manure (1.0 t/ha) + gypsum (10.0 kg/ha) not only produce the maximum quantity of mustard but also maintain the quality and oil content of mustard. Positive outcomes were observed from the interaction between chemical and organic fertilizers. Specifically, the application of treatment 9 enabled a 25% reduction in the use of chemical fertilizers. This presents a promising alternative to solely relying on chemical fertilizers, thereby alleviating pressure on the soil.

5. FUTURE SCOPE

The findings of this study can be utilised as a precedent for further integrated nutrition management research studies. This strategy shows to be a workable substitute for dealing with problems brought on by the overuse of chemical fertilisers in India's trans-Gangetic plains. The ultimate goal is to increase profitability and production while upholding environmental and human welfare. Other organic nutrient sources, such as green manures, green leaf manures, oil cakes, etc., and the application of various nutrients through foliar spray were not studied in this experiment, but they should be before conclusive recommendations can be made to farmers to maximise profits while minimising chemical use in soil.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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