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# Impact of organic modules on higher value crop mustard (*Brassica juncea* (L.)

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**Abstract**
A field experiment conducted at Agronomy Research Farm, N.D. University of Agriculture & Technology, Kumarganj, Faizabad during the Rabi season of 2015-16 evaluated organic modules' impact on high-value crop mustard (*Brassica juncea* L.). Employing Randomized Block Design and replicated three times, the experiment featured seven treatments. Notable treatments included $T_1$ (50% RDF of NPK + 50% N as FYM + 5 kg Zn as ZnO) and $T_7$ (100% of NPK + Recommended dose of S and Zn). Results demonstrated significant enhancements in growth, yield attributes, and quality under $T_7$. Parameters such as plant height, leaf area index, dry matter accumulation, as well as yield attributes and yields, notably increased with $T_7$ during the course of the investigation. This underscores the efficacy of $T_7$ in augmenting the productivity and quality of mustard crops.

**Keywords:** Mustard, bio-fertilizers, FYM, organic sources, neem cake, nitrogen level

## Introduction
Oilseeds are integral to India's economy, comprising 10% of cultivated land and agricultural value, with a projected vegetable oilseed demand of 34 million tonnes by 2020 AD, 14 million tonnes of which is expected from rapeseed-mustard. Indian mustard, a key winter crop, holds a significant position globally, with India leading in area and ranking third in production after China and Canada. Rapeseed-Mustard is the third most important oilseed crop globally, contributing 28.6% to India's oilseed production. India stands among the top oilseed-producing nations, with mustard being the second most important edible oilseed crop after groundnut. During 2013-14, India cultivated 6.5 million hectares of rapeseed-mustard, yielding 7.8 million tonnes, while in Uttar Pradesh alone, 10.26 lakh hectares produced 11.29 lakh tonnes. Oilseeds play a vital role in India's agriculture and economy, providing essential nutrients for human nutrition. With oil content ranging from 33% to 46%, rapeseed & mustard seeds are highly nutritious, containing essential fatty acids like erucic acid, linoleic acid, and oleic acid. After oil extraction, the seed residue is used to produce rapeseed/mustard meal, a crucial component of cattle and poultry feed.

Fertilizers have significantly boosted oilseed production, with balanced formulations being crucial for achieving optimal yields and nutrient efficiency. The right balance of primary, secondary, and micronutrients corrects deficiencies and ensures sustainable production. A balanced supply of plant nutrients is vital for oilseed crops to thrive. Nitrogen is essential for vigorous growth, dark green foliage, and efficient carbohydrate utilization. It plays a pivotal role in early plant establishment, promoting leaf area and root development, and is a key component of various essential compounds. Phosphorus enhances oil content in seeds and influences fatty acid composition positively. Potassium, crucial for plant vitality, aids in stress tolerance, regulates stomatal function, and enhances resistance to lodging and pests, contributing to crop quality. Sulfur and zinc deficiencies can impede oilseed crop productivity, as they are vital for protein and oil synthesis. Sulfur, a key nutrient alongside nitrogen, phosphorus, and potassium, improves seed quality and structural integrity. Balanced fertilization and attention to secondary and micronutrient needs are crucial for maximizing oilseed crop yields and quality, ensuring sustainable agriculture practices for future generations.

The excessive use of agrochemicals over the past 50 years has led to commendable progress but neglected ecological agricultural principles, resulting in stagnant crop yields and various environmental issues. This negligence has caused serious concerns, with warning signs emerging sooner than expected. Indiscriminate use of chemical fertilizers and pesticides has polluted soil, water, and air, diminishing soil health and productivity. Excessive agrochemical use has disrupted the natural harmony among soil, plants, wildlife, and humans.

In response, there is a pressing need to promote organic farming as a solution to mitigate the adverse effects of chemical agriculture. Organic farming involves nourishing the soil with diverse microorganisms and nutrients through compost, farmyard manure (FYM), vermicompost, and biofertilizers. These practices enhance soil organic carbon, supply essential plant nutrients, and improve soil properties. Organic manures are crucial components for maintaining and enhancing soil fertility and productivity. Proper management of organic inputs enhances the efficiency of both native and added nutrients. The proper utilization of organic fertilizers leads to improved and sustainable yields while addressing micro and secondary nutrient deficiencies. This approach enhances nutrient use efficiency, thereby reducing production costs and maintaining soil health and productivity. Incorporating organic manures into soil facilitates soil chemical and biological activity, influencing nutrient availability to crop plants. Organic nutrient management plays a crucial role in sustaining soil health by promoting the accumulation of soil organic matter, beneficial microbes, and enzymes. The addition of organic materials to soil increases organic matter content, crop productivity, and soil biological activity. Organic manures such as farmyard manure, vermicompost, and neemcake serve as rich sources of essential plant nutrients, including trace elements. Farmyard manure, a widely used organic fertilizer in India, provides plants with essential nutrients in readily available forms. Its application improves soil structure, enhances water-holding capacity, and contributes to overall soil physical properties. With nitrogen content ranging from 0.5% to 1.5%, phosphorus from 0.4% to 0.08%, and potassium from 0.5% to 1.9%, farmyard manure serves as a valuable resource for sustainable crop production. The application of farmyard manure (FYM) enhances soil cation exchange capacity and microbial activity, while supplying both macro and micronutrients. This leads to minimized leaching losses, improved buffering capacity, and favorable changes in soil redox conditions. Studies by Patel *et al*. (2007) [66] indicate that FYM improves soil physico-chemical properties, directly releasing essential nutrients, ultimately boosting crop yields. Vermicompost, derived from composting organic wastes with worms, contains vital nutrients such as nitrogen (N), phosphorus ($P_2O_5$), and potassium ($K_2O$), along with micronutrients, hormones, enzymes, and beneficial microorganisms. Its application enriches soil with both macro and micronutrients, enhances water retention, and stimulates microbial activity (Manna and Hagra, 1996) [23]. Neemcake, a by-product of Neem tree fruit and kernel cold pressing, serves as a natural fertilizer rich in organic nitrogen, phosphorus, and potassium. When mixed with soil, it significantly improves plant growth and reduces nitrification. Neemcake is widely used in organic farming and agriculture due to its nutrient-rich composition, including nitrogen (3.56%), phosphorus (1.67%), calcium (Ca) (0.99%), and magnesium (Mg) (0.75%). Biofertilizers play crucial roles in soil fertility and crop productivity, although they cannot entirely replace chemical fertilizers necessary for optimal yields. Phosphate solubilizing bacteria, like Pseudomonas, enhance seed germination and vigor by converting unavailable phosphorus into accessible forms through enzyme secretion. Similarly, Azotobacter inoculants stimulate plant growth and root development by providing fixed nitrogen and combating fungal pathogens, ultimately increasing mineral uptake and nitrogen fixation. These biofertilizers contribute to plant growth and productivity through various mechanisms, including hormone production and nutrient solubilization (Singh *et al*., 2011) [52].

## Materials and Methods

### Experimental site

The experiment took place at the Agronomy Research Farm, Narendra Deva University of Agriculture & Technology, located in Narendra Nagar (Kumarganj), Faizabad (U.P.). Positioned on the left side of the Faizabad-Raibareily main road, it sits approximately 42 km away from the Faizabad district headquarters.

### Climatic conditions of the experimental site

Situated within the subtropical region of the Indo-Gangatic plains, the site experiences hot summers and cold winters. About 80% of its total rainfall occurs during the monsoon season, spanning from July to September, with sporadic showers in winter. Annual precipitation averages around 1200 mm, with hot westerly winds prevailing from April until the onset of the monsoon. Meteorological data, including rainfall, maximum and minimum temperatures, relative humidity, sunshine hours, and evaporation rates observed during the crop season, are detailed in Table 1.

**Table 1:** Meteorological parameters prevailed during crop season (2015-16)

| Month /year | Standard Week | Temperature (°C) | | RH (%) | Evaporation rate (mm) | Total Rainfall (mm) | Sunshine Hours (hr) |
|---|---|---|---|---|---|---|---|
| | | Min. | Max | | | | |
| Nov, 2015 | 45 | 13.2 | 32.6 | 60.1 | 4.9 | 00.0 | 4.6 |
| | 46 | 12.4 | 30.7 | 61.3 | 5.2 | 00.0 | 5.6 |
| | 47 | 9.5 | 27.6 | 68.1 | 1.7 | 00.0 | 6.2 |
| | 48 | 7.8 | 26.1 | 61.8 | 1.7 | 00.0 | 6.9 |
| Dec, 2015 | 49 | 9.4 | 26.1 | 78.8 | 3.6 | 00.0 | 3.5 |
| | 50 | 7.7 | 23.8 | 75.8 | 2.4 | 00.0 | 3.2 |
| | 51 | 5.2 | 23.0 | 63.8 | 2.4 | 00.0 | 3.9 |
| | 52 | 7.1 | 25.0 | 74.5 | 2.9 | 00.0 | 6.1 |
| Jan, 2016 | 1 | 6.5 | 24.9 | 68.4 | 2.4 | 00.0 | 4.9 |
| | 2 | 7.5 | 25.1 | 67.4 | 3.1 | 00.0 | 7.1 |
| | 3 | 6.8 | 20.1 | 77.6 | 2.3 | 00.0 | 2.7 |
| | 4 | 6.2 | 22.7 | 70.5 | 2.2 | 00.0 | 3.1 |
| Feb, 2016 | 5 | 6.5 | 25.6 | 63.7 | 3.1 | 00.0 | 4.6 |
| | 6 | 6.9 | 23.6 | 66.9 | 3.5 | 00.0 | 4.9 |
| | 7 | 6.3 | 28.9 | 60.7 | 3.8 | 00.0 | 4.8 |
| | 8 | 11.6 | 28.9 | 60.2 | 5.2 | 00.0 | 6.1 |
| March, 2016 | 9 | 13.4 | 29.7 | 66.0 | 5.3 | 00.0 | 8.1 |
| | 10 | 9.7 | 28.0 | 61.9 | 4.8 | 1.4 | 7.9 |
| | 11 | 14.5 | 30.9 | 53.9 | 5.1 | 3.2 | 6.1 |
| | 12 | 15.4 | 33.4 | 42.7 | 5.8 | 00.0 | 7.9 |

Table 1. reveals weekly mean minimum and maximum temperatures ranging from 2.9 to 14.7°C and 14.8 to 33.0°C, respectively, throughout the crop season. February 2013 recorded 82.6 mm of rainfall, while evaporation rates ranged from 1.2 mm to 8.7 mm in December and March, respectively. December exhibited the highest relative humidity (82.5%), whereas March saw the most sunshine hours.

### Soil characteristics of experimental field

To assess the soil's physico-chemical traits and fertility status, samples were randomly collected from various locations using a soil auger down to a depth of 0-15 cm before fertilizer application. A composite soil sample representing the entire field was analyzed in the laboratory for its physico-chemical properties. The findings of the physical and chemical analyses are presented in Table 2.

**Table 2:** Physico- chemical characteristics of the experimental site:

| S. No. | Physico-chemical characteristics | Values | Method employed |
|---|---|---|---|
| **A. Physical properties** | | | |
| (I) | Sand (%) | 25.0 | Hydrometer method (Bouyoucos, 1936) [3] |
| (II) | Silt (%) | 49.50 | |
| (III) | Clay (%) | 25.50 | |
| (IV) | Textural class | Silt loam | Triangular method (Lyon *et al.*,1952) [21] |
| **B. Chemical properties** | | | |
| (I) | pH (1:1.25 Soil: water) | 8.2 | Glass electrode pH meter (Jackson, 1973) [13] |
| (II) | Organic carbon (%) | 0.32 | Walkley & Black's rapid titration method (Walkley and Black, 1934) [64] |
| (III) | EC $dSm^{-1}$ at 25 °C | 0.24 | Conductivity Bridge (Jackson 1973) [13] |
| (IV) | Available N (kg $ha^{-1}$) | 136.5 | Alkaline permanganate method (Subbiah and Asija, 1956) [58] |
| (V) | Available $P_2O_5$ (kg $ha^{-1}$) | 14.5 | Olsen's method (Olsen *et al.*, 1954) [30] |
| (VI) | Available $K_2O$ (kg $ha^{-1}$) | 248.5 | Flame photometer (Jackson, 1973) [13] |
| (VIII) | Available Zn (ppm) | 0.54 | Atomic absorption Spectrophotometer (Jackson, 1973) [13] |

## Cropping History

The cropping history for the last five years, detailing the nature of crops grown on the experimental land, is provided in Table 3 to aid in result interpretation and discussion. The details of the experiments given in table 3.

**Table 3:** Cropping history of the experimental field:

| Crop/Year | Crop season | | |
|---|---|---|---|
| | Kharif | Rabi | Summer |
| 2011-12 | Rice | Mustard | Green gram |
| 2012-13 | Rice | Mustard | Green gram |
| 2013-14 | Rice | Mustard | Green gram |
| 2014-15 | Rice | Mustard | Green gram |
| 2015- 16 | Rice | Experimental Crop | Green gram |

**Table 4:** Detail of the experiment

| S. No | Symbol | Treatment combinations |
|---|---|---|
| 1. | $T_1$ | 50% RDF of NPK + 50% N as FYM+ 5kg Zn as ZnO |
| 2. | $T_2$ | FYM + Vermicompost + Neem Cake (each 1/3of recommended N) |
| 3. | $T_3$ | $T_2$ + Intercropping / Trap cropping |
| 4. | $T_4$ | $T_2$ + Hand weeding +Bio–pesticide & Bio-herbicides (Neem based) |
| 5. | $T_5$ | 50% N as FYM + Azotobacter + PSB + Bone meal as a source of P fertilizers |
| 6. | $T_6$ | $T_2$ +Azotobacter + PSB |
| 7. | $T_7$ | 100% of NPK +Recommended dose of S and Zn |
| 8. | $T_8$ | Dummy plot + $T_2$ |

Details of layout plan, calendar of the experiment, and varieties used for the experiments.

The experimental design is randomized block design (RBD) with 3 replications and a total of 8 treatments across 24 plots. The variety used is NDR-8501, with a gross plot size of 6.30 m x 9.90 m and a net plot size of 4.5 m x 7.8 m.

**Table 5:** Calendar of cultural operations

| S. No. | Operation | Date |
|---|---|---|
| 1. | Preparatory tillage | |
| (a) | Ploughing (tractor) | 25/11/2015 |
| (b) | Disking and harrowing | 26/11/2015 |
| 2. | Layout Plan | 27/11/2015 |
| 3. | Sowing | 28/11/2015 |
| 4. | Fertilizer application | |
| (a) | Application of FYM, Neemcake, Vermicompost | 21/11/2015 |
| (b) | Basal application of N.P.K.S and Zn | 28/11/2015 |
| (c) | Top dressing of Nitrogen | 27/12/2015 |
| 5. | Thinning | 25/12/2015 |
| 6. | Intercultural | |
| (a) | Weeding | 26/12/2015 |
| 7. | Irrigation | |
| (a) | First irrigation | 10/0 1/2016 |
| (b) | Second irrigation | 04/02/2016 |
| 8. | Plant protection | |
| (a) | Spraying of Rogar | 26/02/2016 |
| `9. | Harvesting | 17/03/2016 |

Narendra Rai-1 (NDR-8501): A high-yielding oilseed variety developed in 1990 at ND University of Agriculture & Technology, with a plant height of 160-175 cm, 39% oil content, and suitable for irrigated and salt-affected areas.

## Agronomic practices

Agronomic practice encompassed various operations including land preparation involving ploughing and planking, fertilizer application with organic and chemical sources, sowing using a seed drill, thinning to maintain proper spacing, weeding with a khurpi, and irrigation with two applications at specific crop stages. Additionally, plant protection measures involved spraying Rogar to combat aphids, and harvesting occurred at physiological maturity with precautions to minimize shattering losses. Threshing and winnowing were conducted to determine seed and stover yield, contributing to the comprehensive management of the mustard crop experiment.

## Observations recorded

### Growth parameters

Growth parameters were meticulously monitored throughout the experiment. Plant height was measured from the base to the top of the plant at 30, 60, 90 days after sowing (DAS), and at harvest. The number of primary and secondary branches per plant were counted at the same intervals. Dry matter accumulation was determined by sun drying and subsequent oven drying of plant samples, providing insights into biomass production. Leaf area index was calculated using automatic leaf area meter readings at specific intervals, reflecting the canopy development and efficiency of light interception. Additionally, yield attributes such as the number of siliquae per plant, length of siliqua, and number of seeds per siliqua were assessed, contributing to a comprehensive understanding of yield potential and contributing factors.

Test weight (g) was determined by counting and weighing a sample of seeds from each net plot, ensuring accuracy and consistency in measurement. The weight of a thousand seeds was recorded to assess the average test weight of the seeds. Yield (q ha-1) was evaluated comprehensively to determine the overall productivity of the mustard crop. Biological yield was quantified by weighing all above-ground plant parts per plot and converting the values to quintals per hectare. Seed yield (q ha-1) was determined by harvesting, drying, threshing, and cleaning the seeds from individual plots, providing a direct measure of seed production per hectare. Stover yield (q ha-1) was calculated by subtracting the seed yield from the total biological yield, representing the biomass of the plant excluding the seeds. Harvest index (%) was calculated as the ratio of economic yield to biological yield, offering insights into the efficiency of resource allocation towards seed production relative to total plant biomass.

**Qualitative studies**

Oil content (%) was determined using the Soxhlet method as outlined in AOAC (1970). Seeds were dried, crushed, and subjected to extraction to obtain the oil content. 3.13.2 Oil yield (qha-1) was calculated using a specific formula tailored to measure the quantity of oil produced per hectare. NPK Content analysis included determining the nitrogen, phosphorus, and potassium content in both seeds and stover. Nitrogen content (%) was assessed using the Micro-Kjeldahl method (Subbiah and Asija, 1956) [58]. Phosphorus content (%) was determined through the triacid mixture digestion method followed by colorimetric analysis (Jackson, 1973) [13]. Potassium content (%) was analyzed using the Flame photometer method. NPK Uptake (kg ha-1) was calculated to quantify the nutrient absorption by both grain and straw components based on a specified formula.

**Statistical analysis**

Statistical analysis involved conducting an 'f' test to assess the significance of differences among treatments, with conclusions drawn at a 5% probability level. Additionally, critical differences (CD) were computed to ascertain the significance of variances between treatment means (Fisher and Yates, 1963).

**Results**

**Growth parameter**

In plant height, at 30 DAS no any difference was found when applied biofertilizer as well as combination with chemical fertilizers. Similar results were found at 60 DAS. While 90 DAS plant height was slightly increased in treatment $T_5$ as well as at harvest time.

**Table 6:** Effect of different treatments on plant height (cm) of mustard crat different growth stages

| Symbols | Treatments | 30 DAS | 60 DAS | 90 DAS | At harvest |
|---|---|---|---|---|---|
| $T_1$ | 50% RDF of NPK + 50% N as FYM + 5kg Zn as ZnO | 22.80 | 167.50 | 180.70 | 183.20 |
| $T_2$ | FYM + Vermicompost + Neem Cake (each 1/3 of recommended N) | 18.60 | 145.70 | 168.60 | 171.00 |
| $T_3$ | $T_2$ + Intercropping/ Trap cropping | 18.20 | 138.80 | 156.40 | 160.30 |
| $T_4$ | $T_2$ + Hand weeding + Bio-pesticides & Bioherbicides (Neem based) | 21.20 | 162.50 | 176.70 | 177.60 |
| $T_5$ | 50%N as FYM + Azotobacter + PSB + Bone meal as a source of P fertilizers | 21.80 | 166.60 | 182.50 | 184.30 |
| $T_6$ | $T_2$ + Azotobacter + PSB | 21.50 | 164.30 | 179.40 | 181.20 |
| $T_7$ | 100% of NPK + Recommended dose of S and Zn | 23.80 | 180.60 | 187.50 | 190.70 |
| SEm± | | 0.808 | 5.273 | 5.545 | 7.189 |
| CD (P=0.05) | | 2.490 | 16.248 | 17.087 | 22.152 |

For number of braches in mustard crop, no any significantly changes in all the treatments. We have also observed that the leaf area index also no any changes in all the treatments as compared to control.

**Table 7:** Effect of different treatments on number of branches plant$^{-1}$ of mustard crop at different growth stages

| Symbols | Treatments | 30 DAS | 60 DAS | 90 DAS | At harvest |
|---|---|---|---|---|---|
| $T_1$ | 50% RDF of NPK + 50% N as FYM + 5kg Zn as ZnO | 2.30 | 13.40 | 14.10 | 14.05 |
| $T_2$ | FYM + Vermicompost + Neem Cake (each 1/3 of recommended N) | 1.90 | 12.20 | 12.85 | 12.80 |
| $T_3$ | $T_2$ + Intercropping/ Trap cropping | 1.85 | 11.70 | 12.30 | 12.20 |
| $T_4$ | $T_2$ + Hand weeding + Bio-pesticides & Bioherbicides (Neem based) | 2.10 | 12.70 | 13.35 | 13.25 |
| $T_5$ | 50%N as FYM + Azotobacter + PSB + Bone meal as a source of P fertilizers | 2.20 | 13.20 | 13.85 | 13.80 |
| $T_6$ | $T_2$ + Azotobacter + PSB | 2.15 | 12.90 | 13.55 | 13.50 |
| $T_7$ | 100% of NPK + Recommended dose of S and Zn | 2.40 | 14.80 | 15.50 | 15.40 |
| SEm± | | 0.076 | 0.568 | 0.625 | 0.508 |
| CD (P=0.05) | | 0.235 | 1.750 | 1.925 | 1.566 |

**Table 8:** Effect of different treatments on leaf area index of mustard crop at different growth stages

| Symbols | Treatments | 30 DAS | 60 DAS | 90 DAS |
|---|---|---|---|---|
| $T_1$ | 50% RDF of NPK + 50% N as FYM + 5kg Zn as ZnO | 1.55 | 4.95 | 3.70 |
| $T_2$ | FYM + Vermicompost + Neem Cake (each 1/3 of recommended N) | 1.42 | 4.52 | 3.35 |
| $T_3$ | $T_2$ + Intercropping/ Trap cropping | 1.35 | 4.35 | 3.20 |
| $T_4$ | $T_2$ + Hand weeding + Bio-pesticides & Bioherbicides (Neem based) | 1.48 | 4.70 | 3.50 |
| $T_5$ | 50%N as FYM + Azotobacter + PSB + Bone meal as a source of P fertilizers | 1.55 | 4.88 | 3.65 |
| $T_6$ | $T_2$ + Azotobacter + PSB | 1.50 | 4.77 | 3.55 |
| $T_7$ | 100% of NPK + Recommended dose of S and Zn | 1.72 | 5.45 | 4.00 |
| SEm± | | 0.064 | 0.163 | 0.156 |
| CD (P=0.05) | | 0.197 | 0.502 | 0.481 |

For dry matter accumulation, treatment $T_3$ was significantly decreased the dry matter accumulation, while treatment $T_7$ was significantly increased the treatment $T_7$.

**Table 9:** Effect of different treatments on dry matter accumulation (g) plant$^{-1}$ of mustard crop at different growth stages

| Symbols | Treatments | 30 DAS | 60 DAS | 90 DAS | At harvest |
|---|---|---|---|---|---|
| $T_1$ | 50% RDF of NPK + 50% N as FYM + 5kg Zn as ZnO | 2.15 | 26.20 | 51.50 | 65.70 |
| $T_2$ | FYM + Vermicompost + Neem Cake (each 1/3 of recommended N) | 1.75 | 23.40 | 45.80 | 58.60 |
| $T_3$ | $T_2$ + Intercropping/ Trap cropping | 1.63 | 20.10 | 39.20 | 50.10 |
| $T_4$ | $T_2$ + Hand weeding + Bio-pesticides & Bioherbicides (Neem based) | 1.88 | 24.60 | 48.40 | 61.50 |
| $T_5$ | 50%N as FYM + Azotobacter + PSB + Bone meal as a source of P fertilizers | 1.98 | 25.20 | 49.50 | 63.20 |
| $T_6$ | $T_2$ + Azotobacter + PSB | 1.92 | 25.00 | 49.00 | 62.50 |
| $T_7$ | 100% of NPK + Recommended dose of S and Zn | 2.45 | 29.10 | 57.30 | 72.80 |
| SEm± | | 0.084 | 0.981 | 1.866 | 2.680 |
| CD (P=0.05) | | 0.260 | 3.023 | 5.750 | 8.258 |

Treatment $T_5$ was significantly was increased 50% flowering by 9%. Similar result was found for mustard crop maturity.

**Table 10:** Effect of different treatments on 50% flowering and maturity of mustard crop at different growth stages

| Symbols | Treatments | Days taken to 50% flowering | Maturity |
|---|---|---|---|
| $T_1$ | 50% RDF of NPK + 50% N as FYM + 5kg Zn as ZnO | 54.40 | 119.60 |
| $T_2$ | FYM + Vermicompost + Neem Cake (each 1/3 of recommended N) | 53.80 | 118.20 |
| $T_3$ | $T_2$ + Intercropping/ Trap cropping | 51.60 | 113.50 |
| $T_4$ | $T_2$ + Hand weeding + Bio-pesticides & Bioherbicides (Neem based) | 54.00 | 118.60 |
| $T_5$ | 50%N as FYM + Azotobacter + PSB + Bone meal as a source of P fertilizers | 52.70 | 115.90 |
| $T_6$ | $T_2$ + Azotobacter + PSB | 51.80 | 114.00 |
| $T_7$ | 100% of NPK + Recommended dose of S and Zn | 55.00 | 121.00 |
| SEm± | | 1.823 | 4.994 |
| CD (P=0.05) | | 5.619 | 15.387 |

**Table 11:** Effect of different treatments on yield attributes of mustard crop

| Symbols | Treatments | Number of siliquae plant$^{-1}$ | Length of siliquae plant$^{-1}$ | Number of seeds Siliqua$^{-1}$ | Test weight (g) |
|---|---|---|---|---|---|
| $T_1$ | 50% RDF of NPK + 50% N as FYM + 5kg Zn as ZnO | 151.30 | 5.45 | 11.05 | 4.55 |
| $T_2$ | FYM + Vermicompost + Neem Cake (each 1/3 of recommended N) | 137.60 | 4.95 | 10.10 | 4.35 |
| $T_3$ | $T_2$ + Intercropping/ Trap cropping | 128.50 | 4.64 | 9.50 | 4.25 |
| $T_4$ | $T_2$ + Hand weeding + Bio-pesticides & Bioherbicides (Neem based) | 142.80 | 5.12 | 10.50 | 4.60 |
| $T_5$ | 50%N as FYM + Azotobacter + PSB + Bone meal as a source of P fertilizers | 149.20 | 5.33 | 10.95 | 4.65 |
| $T_6$ | $T_2$ + Azotobacter + PSB | 146.00 | 5.20 | 10.70 | 4.62 |
| $T_7$ | 100% of NPK + Recommended dose of S and Zn | 165.30 | 5.95 | 12.10 | 4.75 |
| SEm± | | 5.092 | 0.223 | 0.447 | 0.181 |
| CD (P=0.05) | | 15.683 | 0.687 | 1.378 | 0.558 |

**Table 12:** Effect of different treatments on seed yield (kg ha$^{-1}$), stover yield (kg ha$^{-1}$) and harvest index (%) of mustard crop

| Symbols | Treatments | Seed yield (kg ha$^{-1}$) | Stover yield (Kg ha$^{-1}$) | Harvest index (%) |
|---|---|---|---|---|
| $T_1$ | 50% RDF of NPK + 50% N as FYM + 5kg Zn as ZnO | 17.10 | 55.82 | 23.46 |
| $T_2$ | FYM + Vermicompost + Neem Cake (each 1/3 of recommended N) | 15.32 | 50.28 | 23.45 |
| $T_3$ | $T_2$ + Intercropping/ Trap cropping | 13.82 | 44.49 | 23.79 |
| $T_4$ | $T_2$ + Hand weeding + Bio-pesticides & Bioherbicides (Neem based) | 15.60 | 51.35 | 23.36 |
| $T_5$ | 50%N as FYM + Azotobacter + PSB + Bone meal as a source of P fertilizers | 16.25 | 54.10 | 23.14 |
| $T_6$ | $T_2$ + Azotobacter + PSB | 15.77 | 52.00 | 23.31 |
| $T_7$ | 100% of NPK + Recommended dose of S and Zn | 18.92 | 64.06 | 22.78 |
| SEm± | | 0.710 | 2.284 | 1.260 |
| CD (P=0.05) | | 2.188 | 7.039 | 3.882 |

**Quality parameters of Mustard Plants**

In oil content, treatment $T_1$ was found higher oil content as compared to control as well as other treatments. We have also observed that the treatment $T_6$ and $T_4$ were significantly superior over the treatment $T_2$ (Table). In oil yield, treatment $T_7$ was found significantly higher over control. Similar results were observed the total protein content.

**Table 13:** Effect of different treatments on oil content, oil yield and protein content of mustard crop

| Symbols | Treatments | Oil content (%) | Oil yield (Kg) | Protein content (%) |
|---|---|---|---|---|
| $T_1$ | 50% RDF of NPK + 50% N as FYM + 5kg Zn as ZnO | 40.60 | 6.92 | 19.18 |
| $T_2$ | FYM + Vermicompost + Neem Cake (each 1/3 of recommended N) | 38.50 | 5.89 | 18.25 |
| $T_3$ | $T_2$ + Intercropping/ Trap cropping | 37.65 | 5.19 | 18.13 |
| $T_4$ | $T_2$ + Hand weeding + Bio-pesticides & Bioherbicides (Neem based) | 38.80 | 6.04 | 18.44 |
| $T_5$ | 50%N as FYM + Azotobacter + PSB + Bone meal as a source of P fertilizers | 39.30 | 6.39 | 18.74 |
| $T_6$ | $T_2$ + Azotobacter + PSB | 38.90 | 6.12 | 18.50 |
| $T_7$ | 100% of NPK + Recommended dose of S and Zn | 39.90 | 7.53 | 19.56 |
| SEm± | | 1.302 | 0.199 | 0.497 |
| CD (P=0.05) | | 4.013 | 0.614 | 1.532 |

We have also analysed the nutrient of mustard seed and stover. The total nitrogen content was significantly higher at treatment $T_7$ by 7% as compared to all the treatments. While in stover, no any significantly change on nitrogen content (Table 13).

For uptake of nitrogen in mustard crop, treatment ($T_7$) was uptake highest nitrogen uptake (115.58 kg $ha^{-1}$) which was significantly superior over chemical and other organic manured treatments. The lowest nitrogen uptake (75.69 kg $ha^{-1}$) was found treatment $T_3$ as compared to other treatments.

**Table 14:** Effect of different treatments on Nitrogen Content (%) of mustard crop

| Symbols | Treatments | N content in grain | N content in stover |
|---|---|---|---|
| $T_1$ | 50% RDF of NPK + 50% N as FYM + 5kg Zn as ZnO | 3.07 | 0.85 |
| $T_2$ | FYM + Vermicompost + Neem Cake (each 1/3 of recommended N) | 2.92 | 0.81 |
| $T_3$ | $T_2$ + Intercropping/ Trap cropping | 2.90 | 0.80 |
| $T_4$ | $T_2$ + Hand weeding + Bio-pesticides & Bioherbicides (Neem based) | 2.95 | 0.82 |
| $T_5$ | 50%N as FYM + Azotobacter + PSB + Bone meal as a source of P fertilizers | 3.00 | 0.84 |
| $T_6$ | $T_2$ + Azotobacter + PSB | 2.96 | 0.83 |
| $T_7$ | 100% of NPK + Recommended dose of S and Zn | 3.13 | 0.88 |
| SEm± | | 0.080 | 0.029 |
| CD (P=0.05) | | 0.245 | 0.089 |

**Table 15:** Effect of different treatments on Nitrogen uptake (kg $ha^{-1}$) of mustard crop

| Symbols | Treatments | N uptake by grain | N uptake by stover | Total N Uptake |
|---|---|---|---|---|
| $T_1$ | 50% RDF of NPK + 50% N as FYM + 5kg Zn as ZnO | 52.53 | 47.71 | 100.24 |
| $T_2$ | FYM + Vermicompost + Neem Cake (each 1/3 of recommended N) | 44.63 | 40.83 | 85.46 |
| $T_3$ | $T_2$ + Intercropping/ Trap cropping | 39.99 | 35.70 | 75.69 |
| $T_4$ | $T_2$ + Hand weeding + Bio-pesticides & Bioherbicides (Neem based) | 45.90 | 42.14 | 88.04 |
| $T_5$ | 50%N as FYM + Azotobacter + PSB + Bone meal as a source of P fertilizers | 48.71 | 45.68 | 94.39 |
| $T_6$ | $T_2$ + Azotobacter + PSB | 46.66 | 43.37 | 90.03 |
| $T_7$ | 100% of NPK + Recommended dose of S and Zn | 59.09 | 56.50 | 115.58 |
| SEm± | | 1.648 | 3.216 | 3.626 |
| CD (P=0.05) | | 5.079 | 9.909 | 11.174 |

For economical analysis, we have observed that the cost of cultivation was significantly deased the cost in treatment $T_5$ by 13.5% compared to control $T_1$. While in total gross and net return of the mustard crop were found higher in treatment $T_7$. For B:C (Benefit cost ratio) ratio was found higher in treatment $T_5$ (Table 16).

**Table 16:** Economics analysis of various treatment combinations

| Treatment | Cost of cultivation (Rs $ha^{-1}$) | Gross return (Rs $ha^{-1}$) | Net return (Rs $ha^{-1}$) | B-C Ratio |
|---|---|---|---|---|
| $T_1$ | 22826.5 | 71191 | 48364.5 | 2.11 |
| $T_2$ | 31182.5 | 63794 | 32611.5 | 1.04 |
| $T_3$ | 33982.5 | 57504.5 | 23522 | 0.69 |
| $T_4$ | 32462.5 | 64967.5 | 32505 | 1.00 |
| $T_5$ | 20097.5 | 67705 | 47607.5 | 2.36 |
| $T_6$ | 31582.5 | 65680 | 34097.5 | 1.07 |
| $T_7$ | 25503.5 | 78883 | 53379.5 | 2.09 |

## Discussion

The plant height, number of branches per plant, leaf area index, and dry matter accumulation were significantly influenced by different integrated organic manure and fertilizer treatments. Maximum values for these parameters were observed in treatments with 100% fertilizers (100% NPKS and Zn) and were comparable to treatments with 100% organic manures (FYM + PSB + Azotobacter + Bone meal) and integrated (fertilizer + FYM) treatment. The minimum values were generally seen in treatments involving intercropping ($T_2$ + Intercropping).

The higher plant height, number of branches, leaf area index, and dry matter accumulation in treatments with balanced nutrient supplies, particularly from inorganic fertilizers, can be attributed to increased nutrient uptake, enhanced metabolic processes, and favorable synthesis of growth-promoting constituents in plants. These results align with previous studies by Kumar *et al.* (2004) [19], Das *et al.* (2003) [5], Kashved *et al.* (2010) [17], Rao and Shaktawat (2002) [39], Deol *et al.* (2008) [8], and Shukla *et al.* (2002) [43], highlighting the importance of nutrient balance and integrated nutrient management for achieving optimal growth and productivity in crops. The treatment with organic manures (50%N as FYM + Azotobacter + PSB + Bone meal) showed significant superiority over other treatments. The highest test weight was recorded in the 100% fertilizers treatment (100% recommended NPKS dose applied through chemical fertilizers), followed by the (50%N as FYM + Azotobacter + PSB + Bone meal) treatment. The increase in yield attributes can be attributed to improved vegetative and reproductive traits under proper nutrition from fertilizers and integrated nutrients. Enhanced photosynthesis activity, efficient translocation of photosynthates, and increased nutrient uptake contributed to higher yield attributes. Conversely, treatments with lower nutrient doses (FYM + Vermicompost + Neem Cake + Intercropping/Trap cropping) exhibited minimum yield attributes due to insufficient nutrient availability, resulting in poor yields. Similar findings have been reported by Tripathi *et al*. (2011) [60], Deol *et al*. (2008) [8], and Kashved *et al*. (2010) [17]. Yield, influenced significantly by organic manures, fertilizers, and inoculants, showed maximum seed yield in the treatment with 100% recommended NPKS dose applied through chemical fertilizers, statistically comparable to treatments with fertilizer + FYM and (50%N as FYM + Azotobacter + PSB + Bone meal). Adequate nutrient availability contributed to improved growth parameters and yield attributes, enhancing seed and stover yield collectively. Better translocation of photosynthates due to increased NPK uptake further boosted yields. Conversely, treatments with reduced nutrient supply ($T_2$ + intercropping) exhibited minimum seed and straw yield due to poor growth and yield attributes. Similar results have been reported by Dongarwar *et al*. (2007) [10], Mondal *et al*. (1992) [26], Paraye *et al*. (2009) [33], and Shukla *et al*. (2002) [43]. The oil content in seeds was significantly affected by various organic manures, fertilizers, and bio-inoculants. The highest oil content was observed in the $T_1$ (Fertilizer + FYM) treatment, followed by $T_7$ (100% recommended NPKS dose applied through chemical fertilizers) and $T_5$ (50%N as FYM + Azotobacter + PSB + Bone meal) treatments, while the lowest was in $T_3$ ($T_2$ + Intercropping). Adequate nutrient supply, including N, P, K, and others, likely increased seed vigor and oil content. Pal *et al*. (2010) [31], Singh *et al*. (2006) [46], and Shanker *et al*. (2002) [42] reported similar findings, noting significant increases in oil content with proper nutrient and bio-inoculant application. NPK uptake at harvest was significantly influenced by organic manures, fertilizers, and bio-inoculants, with the highest uptake observed in $T_7$ (FYM + fertilizers), significantly exceeding other treatments. Proper root establishment, enhanced nutrient absorption, and vigorous plant growth likely contributed to this increase. Conversely, $T_3$ ($T_2$ + Intercropping) exhibited the lowest NPK uptake. Mandal *et al*. (2002) [22], Rundala *et al*. (2012) [40], and Singh *et al*. (2009) [48] reported similar outcomes. Regarding economics, the highest total cost of cultivation was in the $T_2$ + Intercropping treatment due to substantial organic manure use. The maximum gross income, net return, and B: C ratio were recorded in $T_1$ (Fertilizer + FYM), whereas the minimum values were in $T_2$ + Intercropping (100% nutrients through organic manures). Comparable results were reported by Tripathi *et al*. (2012) [62], Singh *et al*. (2014) [50], and Singh *et al*. (2005) [47].

## Conclusion

The plant height, number of branches per plant, leaf area index, dry matter accumulation, siliquae per plant, length of siliqua, number of seeds per siliqua, test weight, seed yield, oil content, and NPK uptake were all significantly influenced by various treatments. Notably, $T_7$ (100% NPKS and Zn) consistently demonstrated superior results across multiple growth stages, followed closely by $T_1$ (fertilizer + FYM) and $T_5$ (50%N as FYM + Azotobacter + PSB + Bone meal) treatments. These treatments consistently outperformed others in terms of plant morphology, yield attributes, oil content, and nutrient uptake. Conversely, $T_3$ ($T_2$ + Intercropping) consistently exhibited the lowest performance across these parameters, indicating the importance of proper nutrient management and integrated approaches in maximizing crop productivity. Economically, $T_7$ (100% NPKS and Zn) also stood out with the highest gross income and net return, emphasizing the economic benefits of optimal nutrient application. On the other hand, $T_3$ ($T_2$ + Intercropping) showed the lowest gross income, net return, and B-C ratio, highlighting the financial repercussions of inadequate nutrient supply and suboptimal management practices. These findings underscore the critical role of nutrient management strategies in achieving both agronomic success and economic viability in mustard crop cultivation.

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