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Effect of organic and inorganic sources of nutrient on production and productivity of Indian mustard (*Brassica juncea* L.)

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Abstract
Present experiment entitled "Effect of organic and Inorganic Sources of nutrient on production and productivity of Indian mustard (*Brassica juncea* L.)"" was conducted during the *Rabi* season of 2022 - 23 at Agriculture Research Farm, Rama University, Mandhana, Kanpur. The experiment was laid out in Randomized Block Design (RBD) with three replications and eight treatments *viz*. T_1 = 100% RDF (80:60:40 NPK), T_2 =70% RDF (80:60:40 NPK), T_3 =100% RDF + FYM 10 t ha^{-1}, T_4 =100% RDF + Azotobacter + PSB, T_5 =75% RDF + FYM 25 t ha^{-1} +Azotobacter + PSB, T_6 =100% RDF +FYM 15 t ha^{-1}+Azotobacter + PSB, T_7 =100% RDF + FYM 20 t ha^{-1} + Azotobacter + PSB, T_8 =100% RDF + FYM 10 t ha^{-1} + *Azotobacter* + PSB, T_9 =NAA 125 ppm foliar spray at 30 and 45 DAT. The result of the study revealed that the maximum plant population (9.56), Plant height (128.96 cm), Number of branches/plant (44.82), number of leaves / plant (19.50), Number of siliqua/ plant (121.67) length of siliqua (7.19 cm), number of seeds/ siliqua (17.53), weight of siliqua (10.72 gm), test weight (5.03g) Biological yield/ ha (7784.70 kg), Straw yield (5545.82 kg), and Harvest Index (28.76) was reported in treatment T_7 =100% RDF + FYM 20 t ha^{-1} + Azotobacter + PSB followed by treatment T_5 =75% RDF + FYM 25 t ha^{-1} +Azotobacter + PSB. Basis on these results treatment T_7 can be suggested to the local farmer of Kanpur regions to obtain higher yield and better quality of Mustard.

Keywords: Azotobacter, PSB, FYM, RDF

Introduction
Mustard (*Brassica juncea* L.) is important *rabi* oilseed crop which belongs to family "*Cruciferae*". Mustard Seeds are known by different names in different part of country *e.g*. Sarson, Rai or Raya, Toria or Lahi. While sarson and toria (Lahi) are generally known as rapeseed rai or laha commonly known as mustard. The oil content in mustard seeds varies from 37-49 percent, the seeds are highly nutritive containing 38-57% eruric acid, and 27% oleic acid, 17-25% proteins, 8-10% fibers, 6-10% moisture, and 10-12% extractable substances (Pandey *et al*., 2013) [7]. This is a potential crop in winter (*Rabi*) season due to its wider adaptability and suitability to exploit residual moisture (Mukherjee, 2010).

Globally, rapeseed mustard is grown by more than sixty nations including India. The global mustard occupied area 36.54 Mha with the production of mustard and its oil is around 72.80 MT and 16-18 MT, respectively. India contributes 28.3% and 12.0% in world acreage and production. India produces around 10.11 MT of rapeseed-mustard next to China (15-16 MT) and Europe (14-15 MT) with significant contribution in world mustard industry (Anonymous, 2021a) [1].

In India mustard play significant role in Indian economy, sharing 14% of gross cropped area and accounting nearly 1.5% of gross national production and 80% of the value of all agricultural products. Domestic production of edible oils meets only 50% of the total requirements, while rest is imported. It is third most important edible oilseed crop after soybean and groundnut sharing 27.8% in the India's oilseed economy. (Sahoo *et al*., 2018) [9].

In India it is grown in Rajasthan, UP, Haryana, Madhya Pradesh and Gujarat states. This crop accounts for nearly one-third of the oil produced in India, making it the country's key edible oilseed crop. In Uttar Pradesh state, Indian mustard is grown as a rainfed crop on residual soil moisture successfully owing to its deep root system and cultivated in an area of 0.70 Mha with a production of 0.99 Mt and productivity of 1412 kg ha^{-1} (Anonymous, 2021) [2].

Mustard oil is used primarily for cooking and these are the species valued for vegetable, fodder, condiments and medicine purposes. The Indian system of medicine referred to Brassica compestries as remedy for stomach and skin diseases, elephantiasis etc. Eruca oil is mostly used as lubricant. Mustard oil is not only used for edible purpose but also for industrial purpose like soap making, preparation of hair oil, medicines and in the tanning industry for softening of leather. Oil cakes, green stems and leaves are used as cattle feed and green fodder. The seed and mustard oil have a peculiar pungency due to presence of a glycoside "sinigrin" ($C_{10}H_{16}O_9NS_2K$) thus making it suitable as condiments used in the preparation of pickles, curries and vegetables. The cake left after extraction is utilized as cattle feed and manure containing 25-30% crude protein, 5.1% N, 1.8% P_2O_5 and 1.1% K_2O. Green stem and leaves are a good source of fodder for cattle (Tripathi *et al*., 2010) [12].

Generally, oilseed crops are raised under rainfed conditions with low input and poor management practices leading to lower productivity level. Imbalanced nutrition is one of the important constraints towards higher mustard productivity, oil content and other quality parameters (Lal *et al*., 2015) [4]. In present agriculture scenario use of chemical fertilizer is increasing to boost up crop production. Simultaneously, cost of chemical fertilizer is increased constantly, besides these, indiscriminate use of inorganic fertilizers is injurious to soil health and soil productivity (Eyhorn *et al*., 2007) [3]. Organic manures alone will not supply required nutrients to the crop within short period whereas application of inorganic fertilizers will lead to soil pollution and degradation. Hence, In order to improve crop productivity, soil health and lessen the negative environmental impact Integrated Nutrient Management (INM) is a viable agronomic option. Application of chemical fertilizers along with organic manures are necessary to improve the soil health (Prasad *et al*., 2010) [8]. The nutrient supplied to crops through INM not only restores the soil fertility but also sustain desired level of production over the years (Pal and Pathak, 2016) [13].

The key component of the INM is to decrease the enormous use of chemical fertilizers and accelerating a balance between fertilizer inputs and crop nutrient requirement, optimizing the level of yield, maximizing the profitability, and subsequently reducing the environmental pollution. Yield potentials of the crop, can be maximized by balanced and efficient use of organic and inorganic sources of nutrient (Meena *et al*., 2015) [4]. Balanced nutrient management through conjunctive use of organic, inorganic and bio-fertilizers facilitate profitable and sustainable crop production and also maintain soil health (Singh and Sinsinwar, 2016) [10].

In order to bring the soil well supplied with all the essential plant nutrients and also to maintain it in good health, it is necessary to use organic source like farmyard manure, vermicompost, neemcake and poultry manure which are good source of nutrients required by plants for quality produce. Farm yard manure is a good source of organic matter and play a vital role in improving soil fertility and contains higher nitrogen and phosphorus showed better performance in producing seed yield of mustard (Zamil *et al*., 2004) [14]. Application of FYM improved soil fertility and it has spectacular beneficial effect on physical, chemical and biological properties.

Azotobacter plays an important role in increasing the availability of nitrogen to the plants and helps in boosting the production through nitrogen fixation. Similarly, inoculation with Phosphate Solubilizing Bacteria (PSB) plays a pivotal role in supplementary phosphorus requirement of crop. PSB brings out more amount of fixed or unavailable native phosphorus into soluble and available form to the plants. Regular application of organics in amounts sufficient to meet the requirements of crops not only results in increasing crop yield but also improve soil fertility and organic matter content (Ramesh *et al*., 2008) [6].

The efficiency of both inorganic fertilizers and organic manures may be increased by incorporating inorganic fertilizers with organic materials of varying C: N ratios, before soil application. There is strong evidence that in the presence of organic manures, there is a better utilization of chemical fertilizers and plant is fed more steadily and continuously than with the chemical fertilizers. The efficiency of chemical fertilizers improved significantly when used in combination with organic manures. Secondly, the nutrient losses from the inorganic fertilizers could also be prevented substantially if, organic manures are added in combination on account of improved physico-chemical properties of the soil. Over use of chemical fertilizers harm the biological power of soil, which must be prevented as all nutrient transformation are negotiated by soil microflora. Organic matter is the source of energy to the soil microflora and organic carbon content is considered to be index of the soil health. INM is flexible approach to minimize the use of chemical source of nutrient along with maximization of their use efficiency and farmers profit.

Material and Method

Experiment entitled "Effect of organic and Inorganic Sources of nutrient on production and productivity of Indian mustard (*Brassica juncea* L.)" was conducted during the *Rabi* season of 2022 - 23 at Agriculture Research Farm, Rama university, Mandhana, Kanpur. The experiment was laid out in Randomized Block Design (RBD) with three replications and eight treatments *viz*. T_1 = 100% RDF (80:60:40 NPK), T_2 =70% RDF (80:60:40 NPK), T_3 =100% RDF + FYM 10 t ha^{-1}, T_4 =100% RDF + Azotobacter + PSB, T_5 =75% RDF + FYM 25 t ha^{-1} +Azotobacter + PSB, T_6 =100% RDF +FYM 15 t ha^{-1}+Azotobacter + PSB, T_7 =100% RDF + FYM 20 t ha^{-1} + Azotobacter + PSB, T_8 =100% RDF + FYM 10 t ha^{-1} + *Azotobacter* + PSB The crop was raised at spacing of 45 X 10 cm and plot size of 4X 1.3.6 m. Standard culture practices recommended for mustard was followed uniformly in all experimental plots.

Experimental data was subjected to statistical analysis as per the standard statistical procedure given by Gomez and Gomez (1984) [15]

Table 1: Effect of organic and Inorganic Sources of nutrient on Plant population, Plant Height, Number of branches, Number of Siliqua, Length of Siliqua, Number of seed.

	Plant population	Plant Height (cm)	Number of branches	Number of leaves/ plant	Number of Siliqua	Length of Siliqua	Number of seed
T_1 =100% RDF (80:60:40 NPK)	8.84	115.01	33.29	14.17	108.51	6.04	14.73
T_2 = 70% RDF (80:60:40 NPK)	8.71	109.17	29.26	12.32	103.00	5.66	13.81
T_3 =100% RDF + FYM 10 t ha^{-1}	9.15	120.44	37.39	16.09	113.63	6.43	15.69
T_4 = 100% RDF + Azotobacter + PSB	8.91	117.74	35.89	15.40	111.09	6.15	15.01
T_5 =75% RDF + FYM 25 t ha^{-1} +Azotobacter + PSB	9.54	126.83	43.43	18.90	120.07	6.96	16.98
T_6 =100% RDF +FYM 15 t ha^{-1}+Azotobacter + PSB	9.38	124.73	41.32	17.92	117.69	6.82	16.64
T_7 =100% RDF + FYM 20 t ha^{-1} + Azotobacter + PSB	9.56	128.96	44.82	19.50	121.67	7.19	17.53
T_8=100% RDF + FYM 10 t ha^{-1} + *Azotobacter* + PSB	9.16	123.04	39.72	17.28	116.09	6.54	15.96
CV%	0.23	1.44	1.18	0.53	1.28	0.12	0.28
CD%	NS	4.38	3.57	1.60	3.89	0.37	0.84

Table 2: Effect of organic and Inorganic Sources of nutrient on Weight of siliqua, Weight of seed/ siliqua, Biological Yield, Harvest Index

	Weight of siliqua (gm)	Weight of seed/ siliqua (gm)	Test weight (gm)	Biological Yield (kg/ha)	Straw Yield (kg/ha)	Harvest Index
T_1 =100% RDF (80:60:40 NPK)	11.14	6.75	4.22	5184.87	3804.73	26.62
T_2 = 70% RDF (80:60:40 NPK)	9.25	5.60	3.94	4369.59	3223.93	26.22
T_3 =100% RDF + FYM 10 t ha^{-1}	13.24	8.02	4.50	6248.24	4528.19	27.53
T_4 = 100% RDF + Azotobacter + PSB	11.84	7.18	4.30	5231.44	3828.15	26.82
T_5 =75% RDF + FYM 25 t ha^{-1} +Azotobacter + PSB,	16.37	9.92	4.87	7642.15	5448.28	28.71
T_6 =100% RDF +FYM 15 t ha^{-1}+Azotobacter + PSB,	15.42	9.35	4.77	6843.93	4912.57	28.22
T_7 =100% RDF + FYM 2,0 t ha^{-1} + Azotobacter + PSB	17.69	10.72	5.03	7784.70	5545.82	28.76
T_8 =100% RDF + FYM 10 t ha^{-1} + *Azotobacter* + PSB	13.99	8.48	4.58	6351.95	4600.08	27.58
CV	0.59	0.37	0.09	176.56	126.45	0.22
CD%	1.80	1.12	0.27	535.53	383.53	0.66

Plant Population

The data showed that plant population running $meter^{-1}$ in the all treatments was not influenced significantly during the year. Maximum plant population was recorded under T_7: 100% RDF + FYM 20 t ha^{-1} + *Azotobacter* + PSB followed by the application of T_5: 75% of RDF + FYM 25 t ha^{-1} + *Azotobacter* + PSB as compared to other treatment during the years of study. However, the lowest plant population was noted under the application of treatment 70% RDF (T_2) during the years of investigation.

Plant height

Data showed that plant height was increased in all the treatments over 70% RDF. The increase in plant height in all the treatments was found significant during the year.

Among the treatments at different stage of observation maximum plant height was recorded with the application of 100% RDF + FYM 20 t ha^{-1} + *Azotobacter* + PSB **(**T_7) which was statistically at par with the application of 75% RDF + FYM 25 t ha^{-1} + *Azotobacter* + PSB (T_5) and 100% RDF + FYM 15 t ha^{-1} + *Azotobacter* + PSB (T_6) but significantly superior over all other treatments at all stages of growth during the crop period. The increase in plant height might be due to availability of nutrients throughout the crop growth period by decomposition of FYM. Integrated nutrient management increased the uptake of nutrients by crop contributed to higher vegetative growth. Nitrogen may influence the different physiological processes such as a cell elongation cell division, and chlorophyll production which resulted in better growth attributes. These findings were in agreement with those reported by Hadiyal *et al*. (2017) [16], Khambalkar *et al*. (2017) [17], Kumar *et al*. (2018) [18] and Devkota *et al*. (2020) [19].

Number of branches $plant^{-1}$

Maximum number of branches per plant at all the stages was recorded with the application of 100% RDF + FYM 20 t ha^{-1} + *Azotobacter* + PSB **(**T_7) followed by 75% RDF + FYM 25 t ha^{-1} + *Azotobacter* + PSB (T_5) and minimum at 70% RDF (T_2) during study year. Increase in number of branches $plant^{-1}$ is might be due to increased availability of nutrients with integrated use of 100% RDF with FYM, and biofertilizer. The favorable synthesis of growth promoting constituents in plant system owing to better supply of nutrients resulted in higher number of branches. These results are in close agreement with those of Tripathi *et al*. (2013) [7], Saha *et al*. (2015) [20], Hadiyal *et al*. (2017) [16].

Number of leaves $plant^{-1}$

Number of functional leaves $plant^{-1}$ gradually increased with advancement of crop age and attained maximum at 90 days stage during the year and thereafter decreases gradually. the significantly higher number of functional leaves $plant^{-1}$ was observed with the application of 100% RDF + FYM 20 t ha^{-1}

+ *Azotobacter* + PSB **(**T_7) during the year of experimentation. Variation in number of functional leaves plant^{-1} within 100% RDF + FYM 20 t ha^{-1} + *Azotobacter* + PSB **(**T_7), 75% RDF + FYM 25 t ha^{-1} + *Azotobacter* + PSB (T_5) and 100% RDF + FYM 15 t ha^{-1} + *Azotobacter* + PSB (T_6) was found statistically at par during the year at all growth stages. While the lowest number of functional leaves plant^{-1} of Indian mustard was recorded with 70% RDF (T_2) at all the stages during the year of study. Increase in number of functional leaves plant^{-1} is might be due to increased plant height and maximum availability of nutrients with integrated use of 100% RDF with FYM, and biofertilizer. The favorable synthesis of growth promoting constituents in plant system owing to better supply of nutrients resulted in higher number of leaves.

Yield attributes

Yield of any crop is generally based on two major factors i.e. yield plant^{-1} and plant population per unit area. Data pertaining in yield attributes mainly, number of siliqua plant^{-1}, siliqua length**,** number of seeds siliqua $^{-1}$, weight of siliqua plant^{-1}, weight of seeds plant^{-1} and 1000-grain weight of Indian mustard was recorded at physiological maturity are presented in Table 2 clearly revealed that these attributes were significantly influenced by different combination of organic and inorganic sources of nutrients in comparison to 70% RDF alone during the year of experimentation.

Among the different organic and inorganic sources of nutrients, 100% RDF + FYM 20 t ha^{-1} + *Azotobacter* + PSB **(**T_7), had resulted in significantly highest yield attributing characters which was statistically on par with 75% RDF + FYM 25 t ha^{-1} + *Azotobacter* + PSB (T_5) and was significantly superior over the other combined application of organic and inorganic sources of nutrients. However, the significantly lower yield attributing characters was observed with the application of 70% RDF (T_2) during the year.

Enhanced yield attributes with the combined application of organic and inorganic source of nutrient, which contributed favourable condition for plant growth by increasing the availability of nutrients to plant and enhancing the branching and leaf area for photosynthesis.

Yield

Biological Yield

Effect of organic and inorganic sources of nutrient on biological yield of Indian mustard is presented in table 2. showed significant increase in all the treatments over 70% RDF alone (T_2) during the study year.

Maximum biological yield 7784.70 kg ha^{-1} was recorded with T_7 (100% RDF + FYM 20 t ha^{-1} + *Azotobacter* + PSB) followed by 7642.15 kg ha^{-1} with T_5 (75% RDF + FYM 25 t ha^{-1} + *Azotobacter* + PSB) and minimum 4369.59 kg ha^{-1} at 70% RDF (T_2), during the year. It was also observed that integration of 100% RDF + FYM 10 t ha^{-1} (T_3) showed significant increase in biological yield over 100% RDF + *Azotobacter* + PSB (T_4), 100% RDF (T_1) and 70% RDF (T_2) alone respectively during the study year.

The increase in biological yield with the application of T_7 (100% RDF + FYM 20 t ha^{-1} + *Azotobacter* + PSB) ws mainly due to increase in dry matter and number of branches and leaves, which was the result of increase in plant height, total nutrient uptake, water holding capacity and fertility of soil.

Seed and stover Yield

The data presented in Table 2 clearly revealed that all the treatments showed significant difference in grain and stover yield due to different combinations of organic and inorganic sources of nutrient over 70% RDF alone during the study year.

Among various combinations of organic and inorganic sources of nutrient were concerned, application of 100% RDF + FYM 20 t ha^{-1} + *Azotobacter* + PSB **(**T_7) being at par with the application of 75% RDF + FYM 25 t ha^{-1} + *Azotobacter* + PSB (T_5) recorded significantly maximum seed and stover yield as compared to rest of the treatment combinations and also produce 95.42% higher grain and 72.02% higher stover yield over the application where 70% RDF (T_2) alone were applied. It was also observed that integration of 100% RDF with FYM @ 20 t ha^{-1} and *Azotobacter* + PSB produce 62.22% higher grain and 45.76% stover yield over the application where 100% RDF (T_1) alone were applied.

Integration of 75% RDF with FYM@ 25t ha^{-1} and *Azotobacter* + PSB (T_5) also influenced 91.49% higher grain yield 69.00% higher stover yield over the application where 70% RDF (T_2) alone were applied and also enhanced grain yield 58.96% and stover yield 43.20% over the application where 100% RDF (T_1) alone were applied, during the year of experimentation. Increase in grain and stover yield might be due to increase in growth and yield attributes of Indian mustard due to integration of organic and inorganic source of nutrient. Organics besides release of their own nutrients might have increase the nutrient use efficiency of applied inorganic fertilizer in Indian mustard. Adequate supply of available nutrients to crop resulting in better growth and development ultimately reflected into better grain and stover yields. The increase in yields with biofertilizers was mainly due to the increase in almost all growth and yield contributing characters, which eventually lead to a significant increase in grain and stover yields.

Harvest index

Harvest index is the ratio of grain yield to the biological yield. A perusal of the data presented in table-2 revealed that harvest index was significantly influenced by various combinations of organic and inorganic sources of nutrient during the year.

Among various combinations of organic and inorganic sources of nutrient were concerned, Application of 100% RDF + FYM 20 t ha^{-1} + *Azotobacter* + PSB **(**T_7) recorded significantly highest harvest index than the other combinations of organic and inorganic sources of nutrients and was statistically at par with the application where 75% RDF + FYM 25 t ha^{-1} + *Azotobacter* + PSB (T_5) and 100% RDF + FYM 15 t ha^{-1} + *Azotobacter* + PSB (T_6) were applied. It was also observed that integration of 100% RDF + FYM 10 t ha^{-1} (T_3) showed significant increase in harvest index over 100% RDF + *Azotobacter* + PSB (T_4), 100% RDF (T_1) and 70% RDF alone respectively during the study year. While application of 70% RDF (T_2) alone attain significantly lower harvest index as compared to other combinations of organic and inorganic sources of nutrient during the year of experimentation.

The increase in harvest index with the application of 100% RDF + FYM @ 20 t ha^{-1} + *Azotobacter* + PSB **(**T_7) was mainly due to higher grain yield as compared to biological yield which was ultimately the result of maximum number of siliqua plant^{-1} and number of seeds siliqua^{-1} that obtain from an adequate supply of nutrient during crop growth. It has been established that the efficiency of inorganic fertilizer can be greatly increased through its integration with organic manures.

Economics

The data presented in table 2 pertaining to Economics of mustard showed that it was influenced by various combinations of organic and inorganic sources of nutrient. Application of 75% RDF + FYM 25 t ha^{-1} + *Azotobacter* + PSB **(**T$_5$) exhibited maximum average cost of cultivation (41689.61 ₹ ha^{-1}), while maximum average gross return of (130337.75 ₹ ha^{-1}), net return (90218.90 ₹ ha^{-1}) and benefit: cost ratio (₹ 2.25 ₹$^{-1}$ invested) was observed with the application 100% RDF + FYM 20 t ha^{-1} + *Azotobacter* + PSB **(**T$_7$) among all the combinations of organic and inorganic sources of nutrient, during the year of experimentation.

The higher benefits are attributed to higher yield and high market price of crops. The higher B: C ratio under these treatments were because of more gross returns obtained and marginal decrease in cost of cultivation invested under these systems. These findings are close conformity with the results reported by Tripathi *et al*. (2010) [12], Tripathi *et al*. (2013) [7], Khambalkar *et al*. (2017) [17], Singh and Singh (2016) [10], Maurya *et al*. (2020) [21], Jaiswal *et al*. (2021) [22], and Saxena *et al*. (2022). However, cultivation of Indian mustard without organic fertilizer showed lower gross and net returns and benefit: cost ratio due to lower productivity of crop.

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