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The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2022; 11(7): 2049-2055

www.thepharmajournal.com
Received: 24-05-2022
Accepted: 27-06-2022

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Effect of integrated nutrient management approach on productivity and profitability of mustard (*Brassica juncea* L.)

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Abstract
A field experiment was conducted at Crop Research Center, Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut, Uttar Pradesh, with a view to compare the production potential under different integrated nutrient management and also to find out the economic viability of this cultivar for soil quality. The treatments comprised of T_1 (control), T_2 RDF (-S), T_3 RDF (+S), T_4 125% RDF (+S), T_5 100% RDF (-S) + 4 ton FYM, T_6 100% RDF (-S) + 1.25 ton Vermicompost, T_7 100% RDF (-S) + 2 ton FYM + 0.6 ton Vermicompost, T_8 75% RDF (-S) + 4 ton FYM, T_9 75% RDF + 1.25 ton Vermicompost and T_{10} 75% RDF + 2 ton FYM + 0.6 ton Vermicompost exhibited significant influence on yield attributes and yield of mustard as compared to the application of 100% RDF alone. The maximum gross return was obtained in T_7 followed by T_{10} and T_6. The highest net return was obtained in T_7 followed by T_{10} and T_6, while minimum gross return and net return was obtained in T_1 during both the years. Application of 100% RDF (-S) + 2 ton FYM + 0.6 ton Vermicompost (T_7) and 75% RDF + 2 ton FYM + 0.6 ton Vermicompost (T_{10}) recorded higher gross return, net return and B:C ratio due to higher cost of FYM and vermicompost. Higher values of B: C ratio (3.47 & 3.88) was obtained in T_7 during 2019-20 and 2020-21.

Keywords: Mustard, integrated nutrient management, production potential, profitability

Introduction
Mustard, as a *Rabi* crop, is an important oil seed crop next to sunflower, with 30-40% protein content and high nutritive-value. Relatively cool temperatures with a fair supply of soil moisture during the growing season and a dry harvest period is required for mustard. Mustard is cultivated mostly sub temperate climates. It is also grown in certain tropical and sub-tropical regions as a cold weather crop. Indian mustard is reported to tolerate annual precipitation of 500 to 4200 mm, annual temperature of 6 to 27 ^{0}C and soil pH of 4.3 to 8.3

The meal remaining as byproduct after extraction of oil is another valuable product obtained from the rapeseed- mustard seeds. It contains about 40% protein with a favourable composition of amino acids, including comparatively high content of essential sulphuric-amino acids, methionine and cysteine (Downey and Bell, 1990). Mustard seed in general, contains 30-33% oil, 17-25% proteins, 8-10% fibers, 6-10% moisture, and 10-12% extractable substances (Hassan *et al*. 2011) [1].

In addition, it is also rich source of health benefiting minerals. Calcium, manganese, copper, iron, selenium and zinc are some of the minerals, especially concentrated in these seeds. However, in comparison to the other popular sources such as soybean, rapeseed mustard meal contains high amount of anti- nutritional compounds called glucosinolate. Calcium helps build bone and teeth. Manganese is used by the body as a co-factor for the antioxidant enzyme superoxide dismutase. Copper is required in the production of red blood cells. Iron is required for the red blood cell formation and cellular metabolism. Indian mustard oil contains minimum amounts of saturated fatty acids as compared to other vegetable oils. The extracted oil is mainly used for edible purposes in India and other South Asian countries (Sharma *et al*. 2002) [2]. It also has considerable amounts of the two essential fatty acids *i.e*. linoleic and linolenic acid. The oil free meal also contains proteins and minerals. The seed cake is used as feed for cattle. Glucosinolates-treated cake is better for animal health.

Production of oilseed in India during 1950-51 was 5.16 mt, which has increased to 42.0 mt in 2020-21. India ranks third in the world in oilseed brassica production after China and Canada.

In domestic agriculture oilseeds occupy 14% of the country's gross cropped area, and nearly 6% of the gross national production. India accounts for 12-15% of worlds oilseed area, 7-8% of worlds oilseed output, and 6-7% of worlds vegetable oil production. According to an estimate by National Council of Applied Economic Research (NCAER), the demand for edible oil was projected at 10 million tons against the domestic production of 6.7- 7.0 mt. The shortfall of 3.0- 3.3 mt was expected to be met by importing oil. The NCAER predicts that in the year 2015, the demand for oil in India would be 20 mt per annum- considering the present domestic edible oil supply of 7 mt per annum, a shortfall of 13 mt per annum is envisaged in the year 2015. To bridge this gap, a growth rate in India has to be maintain 4% yearly. In the event of failure to achieve the required growth rate, India would continue to spend huge foreign exchange in import of edible oil.

In the world, India ranks first in castor, sesame and safflower, second in groundnut, third in rapeseed-mustard, fourth in linseed and fifth in soybean. Although, rapeseed- mustard is grown all over India in different ecosystems and cropping sequences, it is mainly confined to north western and central regions. Four states namely, Rajasthan, Uttar Pradesh, Haryana and Madhya Pradesh account for nearly 78% of the acreage and 80% of the production of rapeseed- mustard. Rajasthan occupies a prime position amongst the states. Uttar Pradesh is the second largest rapeseed- mustard producing states with acreage of 11.48 lakh ha, 15.10 lakh tonnes production and with an average yield of 9.10 q ha^{-1} yield in 2020-21. The state of Uttar Pradesh is divided in to four regions: Central, Western, Eastern, and Bundelkhand regions.

Today, for the country of India's dimension, with no scope for horizontal expansion and complexity of problems and challenges, there is no alternative but continue to improve productivity without further degrading its natural resources that too in a sustainable manner. In this context there is need to adopt a rationalist organic farming approach to have an 'Evergreen Revolution'. This has led to the concept of integrated nutrient management (INM) in recent years to improve and maintain the soil health. Besides this, with escalating cost of energy based fertilizer material, limited fossil fuels, INM approach combines the use of organic sources along with fertilizers, which would be remunerative for getting higher yields with considerable fertilizer economy.

Material and Methods

The experiment was carried out at Crop Research Centre, Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut (U.P.) to study the influence of different zinc enriched and organic sources on productivity and profitability of mustard in Randomized Block Design with 10 treatments (Table 1), replicated four times. The maximum and minimum temperatures recorded were 40.0 ºC and 4.6 ºC during the crop growth period. Relative humidity ranges between 37-83% during crop growth period. The area receives mean annual rainfall between 650-805 mm. The soil of the experimental field was sandy loam in texture, low in available nitrogen (219.0 kg ha^{-1}) and organic carbon (0.45%), medium in available phosphorous (16.9 kg ha^{-1}) and potassium (244.3 kg ha^{-1}), available zinc (0.77), iron 9.42 (mg kg^{-1}) and slightly alkaline (pH 7.7) in reaction with electrical conductivity of 0.19 dS m^{-1}. The crop variety Pusa Vijay was sown on October 16 & 18, 2019 & 2020 and harvested on 1 & 3 March 2020 & 2021. The seed rate was 5 kg ha^{-1}. The recommended dose of nitrogen (120 kg ha^{-1}) was applied in two equal split, the half as basal and the remaining half was top dressed 2 times at the time of first and second irrigation. The whole quantity of potassium (40 kg ha^{-1}) was applied as basal dose through Muriate of Potash at 8-10 cm depth along with half dose of nitrogen prior to sowing. Phosphorous was applied as basal dose (50 kg ha^{-1}) through DAP. Vermicompost (1.25 t ha^{-1}) and FYM (4.0 t ha^{-1}) were applied in the field as per treatments and was thoroughly mixed at the time of sowing. Zinc was applied at the time of sowing in the form of Zinc sulphate. The seed was treated with Azotobacter @200g / 10 kg seed which was applied as per treatments before the sowing. One thinning was done after 30 days of sowing to maintain a plant to plant distance of about 15 cm. Weeding and hoeing operation were performed manually after first and second irrigation at proper soil moisture condition of the soil. At the harvest, number of siliquae plant^{-1}, 1000 seed weight, seed yield and straw yield were calculated. Economics of treatments were computed on the basis of prevailing market price of inputs and outputs under each treatment. The total cost of cultivation of crop was calculated on the basis of different operations performed and materials used for raising the crop including the cost of fertilizers and seeds. The cost of labour incurred in performing different operation was also included. Statistical analysis of the data was done as per the standard analysis of variance technique for the experimental designs following SPSS software based programme, and the treatment means were compared at $P<0.05$ level of probability using t-test and calculating CD values.

Result and Discussion

Effect of different integrated nutrient management on yield attributes of mustard

Yield attributes *viz*., number of siliquae plant^{-1}, siliqua length (cm), number of seed siliqua^{-1} and weight of 1000 grains of mustard were affected significantly by various treatments involving different integrated nutrient management practices (Table 1 and Fig 1).

From the given data (Table 1) it can be inferred that the maximum number of siliquae plant^{-1} (277.4 & 282.9 plant^{-1}) were produced in the treatment T_7 (100% RDF (-S) + 2 ton FYM + 0.6 ton Vermicompost) which was found to be on par with T_{10} (75% RDF + 2 ton FYM + 0.6 ton Vermicompost) and T_6 (100% RDF (-S) + 1.25 ton Vermicompost). However, the lowest number of siliquae plant^{-1} (201.9 & 205.9 plant^{-1}) was recorded in treatment T_1 (Control), which was significantly lower than rest of the other treatments. The results were in accordance with those reported by Yadav *et al.* (2013) and Kansotia *et al.* (2015) [4].

Table 1: Effect of nutrient management on yield attributing characters of mustard

S. No.	Treatments	Yield attributing characters							
		Number of siliquae plant^{-1}		Siliqua Length (cm)		Number of seeds siliqua^{-1}		1000-seed weight (g)	
		2019-20	2020-21	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21
T_1	Control	201.9	205.9	3.1	3.4	11.0	11.7	3.5	3.7
T_2	RDF (-S)	233.2	237.9	3.6	3.9	11.8	12.5	4.3	4.6
T_3	RDF (+S)	236.1	240.8	3.9	4.3	11.9	12.6	4.4	4.7
T_4	125% RDF (+S)	238.1	242.9	4.0	4.4	12.0	12.7	4.5	4.8
T_5	100% RDF (-S) + 4 ton FYM	250.3	255.3	4.7	5.1	12.2	12.9	4.7	5.0
T_6	100% RDF (-S) + 1.25 ton Vermicompost	268.8	272.9	5.1	5.5	12.3	13.0	4.9	5.2
T_7	100% RDF (-S) + 2 ton FYM + 0.6 ton Vermicompost	277.4	282.9	5.4	5.9	12.3	13.0	5.0	5.3
T_8	75% RDF (-S) + 4 ton FYM	240.5	245.3	4.2	4.6	12.1	12.8	4.6	4.9
T_9	75% RDF + 1.25 ton Vermicompost	248.4	253.4	4.5	4.9	12.2	12.9	4.6	4.9
T_{10}	75% RDF + 2 ton FYM + 0.6 ton Vermicompost	270.0	275.4	5.2	5.7	12.3	13.0	5.0	5.3
	SEm±	9.25	9.78	0.16	0.17	0.43	0.45	0.16	0.17
	CD (P = 0.05)	26.62	28.14	0.46	0.50	1.24	1.31	0.47	0.50

Significantly higher siliqua length (5.4 & 5.9 cm) was recorded in treatment T_7 (100% RDF (-S) + 2 ton FYM + 0.6 ton Vermicompost), which was statistically found to be on par with, T_{10} (75% RDF + 2 ton FYM + 0.6 ton Vermicompost) and T_6 (100% RDF (-S) + 1.25 ton Vermicompost). Treatment T_1 (Control) recorded the lowest siliqua length (3.1 & 3.4 cm) and next in order was treatment T_2 (100% RDF). It might be due to increased and prolonged availability of nutrients from integrated use of vermicompost, sulphur and FYM, which ultimately resulted in rapid cell multiplication and cell elongation under sufficient nutrient supply. The results were in accordance with those reported by Yeshpal *et al.* (2004) [5], Thaneshwar (2017) [6] and Singh (2005) [7].

It is evident from the data that the significantly higher number of seed siliqua^{-1} (12.3 & 13.0) were produced in treatment T_7 (100% RDF (-S) + 2 ton FYM + 0.6 ton Vermicompost) followed by T_{10} (75% RDF + 2 ton FYM + 0.6 ton Vermicompost) and T_6 (100% RDF (-S) + 1.25 ton Vermicompost). Treatment T_1 recorded lowest number of seed siliqua^{-1} (11.0 & 11.7) followed by T_2 (100% RDF) during 2019-20 & 2020-21. Adequate nutrients availability to the crop as a result of increment in photosynthesis as well as growth led to increase in the number of seed siliqua^{-1}. These findings were almost similar to the results reported by Sharma *et al.* (2007) [8] and Mehdi and Singh (2007) [9].

Maximum 1000- seed weight (5.0 & 5.3 g) was recorded in T_7 (100% RDF (-S) + 2 ton FYM + 0.6 ton Vermicompost) followed by T_{10} (75% RDF + 2 ton FYM + 0.6 ton Vermicompost) and T_6 (100% RDF (-S) + 1.25 ton Vermicompost), whereas the lowest 1000- seed weight (3.5 & 3.7 g) was recorded in T_1 (Control) during both the years. The integrated application of vermicompost and FYM might increase availability of plant nutrients which result into better nourishment of plants and the formation of bold seeds, ultimately increased weight of seed. The results were similar to the findings reported by Khan *et al.* (2009) and Mouriya *et al.* (2013) [10].

Effect of different integrated nutrient management on Productivity

Data with regard to the effect of integrated nutrient management on seed yield, stover yield, biological yield and harvest index of mustard crop are mentioned in Table 2 and depicted in Fig 2.

Among the different integrated nutrient management, the treatment T_7 (100% RDF (-S) + 2 ton FYM + 0.6 ton Vermicompost) exhibited significantly higher seed yield (24.3 & 25.7 q ha^{-1}), which was statistically on par to T_{10} (75% RDF + 2 ton FYM + 0.6 ton Vermicompost) and T_6 (100% RDF (-S) + 1.25 ton Vermicompost). Treatment T_1 (Control) with no application of any fertilizer recorded lowest seed yield of 10.2 & 11.3 q ha^{-1}. About 138.2 & 127.4%, 132.3 & 115.9% and 123.5 & 103.5% increase in seed yield was recorded by T_7 (100% RDF (-S) + 2 ton FYM + 0.6 ton Vermicompost), T_{10} (75% RDF + 2 ton FYM + 0.6 ton Vermicompost) and T_6 (100% RDF (-S) + 1.25 ton Vermicompost) respectively over treatment T_1 (Control) during 2019-20 & 2020-21. The maximum seed yield was recorded due to integrated application of vermicompost and FYM, chemical fertilizers and biofertilizers. This might be due to slow release of nutrient from vermicompost and FYM leading to reduced loss of nitrogen and efficient use of Macro and micronutrients. The production of growth promoting and antifungal substances by Azotobacter and nitrogen fixation was possibly the reason for higher yields.

Table 2: Effect of nutrient management on seed, stover, biological yield and harvest index (%) of mustard crop

S. No.	Treatments	Yield (q ha^{-1})						Harvest Index (%)	
		Seed		Stover		Biological			
		2019-20	2020-21	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21
T_1	Control	10.2	11.3	65.1	66.2	75.2	77.3	13.6	14.6
T_2	RDF (-S)	16.2	17.1	80.2	79.6	96.4	96.7	16.8	17.7
T_3	RDF (+S)	17.5	18.2	84.3	84.3	101.8	102.5	17.2	17.8
T_4	125% RDF (+S)	18.8	19.6	87.1	87.2	105.9	106.8	17.8	18.4
T_5	100% RDF (-S) + 4 ton FYM	21.9	22.1	93.2	94.3	115.1	116.4	19.0	19.0
T_6	100% RDF (-S) + 1.25 ton Vermicompost	22.8	23.0	95.4	96.7	118.2	119.7	19.3	19.2
T_7	100% RDF (-S) + 2 ton FYM + 0.6 ton Vermicompost	24.3	25.7	96.4	99.9	120.7	125.6	20.1	20.5
T_8	75% RDF (-S) + 4 ton FYM	19.4	20.4	88.2	90.0	107.6	110.4	18.0	18.5
T_9	75% RDF + 1.25 ton Vermicompost	20.7	21.7	90.9	93.1	111.6	114.7	18.5	18.9
T_{10}	75% RDF + 2 ton FYM + 0.6 ton Vermicompost	23.7	24.4	95.7	97.1	119.4	121.5	19.8	20.1
	SEm±	0.71	0.74	3.04	3.20	3.75	3.93	0.66	0.65
	CD (P = 0.05)	2.04	2.14	8.80	9.24	10.85	11.38	NS	NS

In the same way, stover yield of mustard (Table 2) was significantly influenced by different integrated nutrient management. Results revealed that the differences in stover yield were found significant due to different treatments. Though significantly higher stover yield 96.4 & 99.9 q ha^{-1} was recorded under T_7 followed by T_{10} and T_6. The lowest stover yield (65.1 & 66.2 q ha^{-1}) was recorded in T_1 (control) during both the years. Similar trend was observed in Biological yield, whereas maximum harvest index (20.1 & 20.5%) was recorded in T_7. The lowest harvest index recorded with T_1 (Control) plot. The increase in stover yield was mainly due to increased growth attributing characters like plant height and number of branches. The use of organic manure like vermicompost, FYM and biofertilizers in conjunction with macro and micronutrients had profound effect on vegetative growth due to improved nutrients availability in the soil for longer time with progressive decompositions of FYM. These findings are in conformity with the results of Hussain *et al.* (2008) [11], Vivek *et al.* (2009) [12], Sattar *et al.* (2010) [13], Singh *et al.* (2010) [14] and Parihar *et al.* (2014) [15].

Economics

From Table 3 it can be seen that among the various nutrient levels, the cost of cultivation (₹ ha^{-1}) varied from 16359 to 28520 & 17152 to 29685 ₹ ha^{-1}. The highest cost of cultivation was registered with the application of 100% RDF (-S) + 2 ton FYM + 0.6 ton Vermicompost (T_7) followed by 75% RDF + 2 ton FYM + 0.6 ton Vermicompost (T_{10}) and 100% RDF (-S) + 1.25 ton Vermicompost (T_6) while the application of no fertilizer (Control) registered the lowest cost of cultivation. Maximum gross returns (127455 & 144770 ₹ ha^{-1}) was obtained by the application of 100% RDF (-S) + 2 ton FYM + 0.6 ton Vermicompost (T_7) followed by 75% RDF + 2 ton FYM + 0.6 ton Vermicompost (T_{10}) and 100% RDF (-S) + 1.25 ton Vermicompost (T_6).

Table 3: Effect of nutrient management on cost of cultivation, gross return, net return (₹ ha^{-1}) and B: C ration of mustard crop

S. No.	Treatments	Profitability (Rs ha^{-1})							
		Cost of cultivation (₹ ha^{-1})		Gross return (₹ ha^{-1})		Net return (₹ ha^{-1})		B: C ratio	
		2019-20	2020-21	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21
T_1	Control	16359	17152	57195	66995	40836	49843	2.50	2.91
T_2	RDF (-S)	22809	23365	87360	98295	64551	74930	2.83	3.21
T_3	RDF (+S)	23989	24469	94020	104555	70031	80086	2.92	3.27
T_4	125% RDF (+S)	24989	25259	100485	112060	75496	86801	3.02	3.44
T_5	100% RDF (-S) + 4 ton FYM	27169	27761	115815	125750	88646	97989	3.26	3.53
T_6	100% RDF (-S) + 1.25 ton Vermicompost	27284	27965	120330	130655	93046	102690	3.41	3.67
T_7	100% RDF (-S) + 2 ton FYM + 0.6 ton Vermicompost	28520	29685	127455	144770	98935	115085	3.47	3.88
T_8	75% RDF (-S) + 4 ton FYM	25104	25567	103440	116520	78336	90953	3.12	3.56
T_9	75% RDF + 1.25 ton Vermicompost	25284	25765	109890	123550	84606	97785	3.35	3.80
T_{10}	75% RDF + 2 ton FYM + 0.6 ton Vermicompost	27989	28357	124560	137785	96571	109428	3.45	3.86
	SEm±	-	-	3794	4235	2896	3320	0.11	0.13
	CD (P = 0.05)	-	-	10974	12251	8377	9602	0.33	0.37

The lowest Gross return of 57195 & 66995 ₹ ha^{-1} was obtained in treatment T_1 (Control). Maximum net return of 98935 & 115085 ₹ ha^{-1} was recorded by the application of 100% RDF (-S) + 2 ton FYM + 0.6 ton Vermicompost (T_7) followed by 75% RDF + 2 ton FYM + 0.6 ton Vermicompost (T_{10}) and 100% RDF (-S) + 1.25 ton Vermicompost (T_6). However, the maximum Benefit cost ratio of 3.47 & 3.88 was obtained by the application of 100% RDF (-S) + 2 ton FYM + 0.6 ton Vermicompost (T_8) followed by 75% RDF + 2 ton FYM + 0.6 ton Vermicompost (T_{10}) and 100% RDF (-S) + 1.25 ton Vermicompost (T_6) during both the years. The higher net returns and BCR was mainly due to increase in seed yield. Similar results recorded by Kumpawat (2004), Singh and Meena (2004) and Tripathi *et al.* (2011).

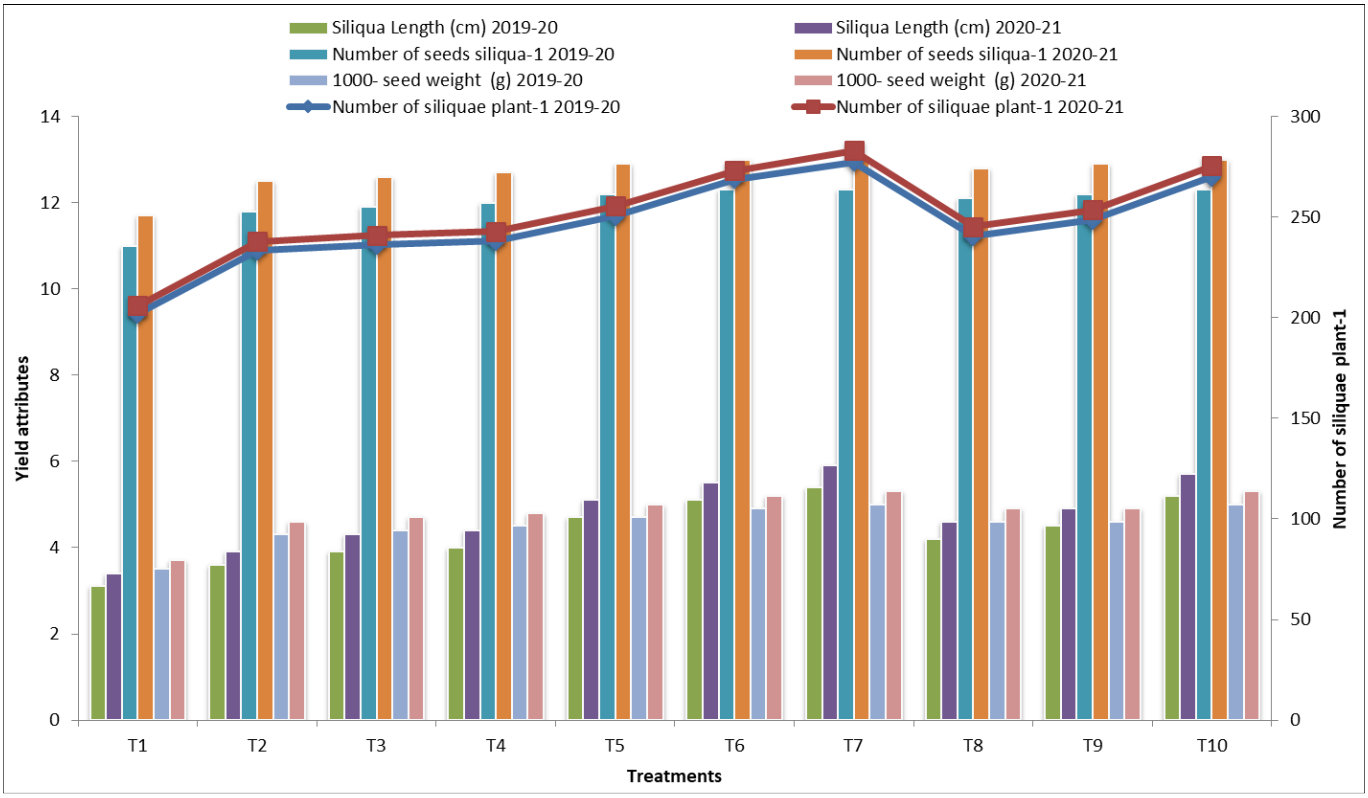

Fig 1: Effect of integrated nutrient management on yield attributes of mustard

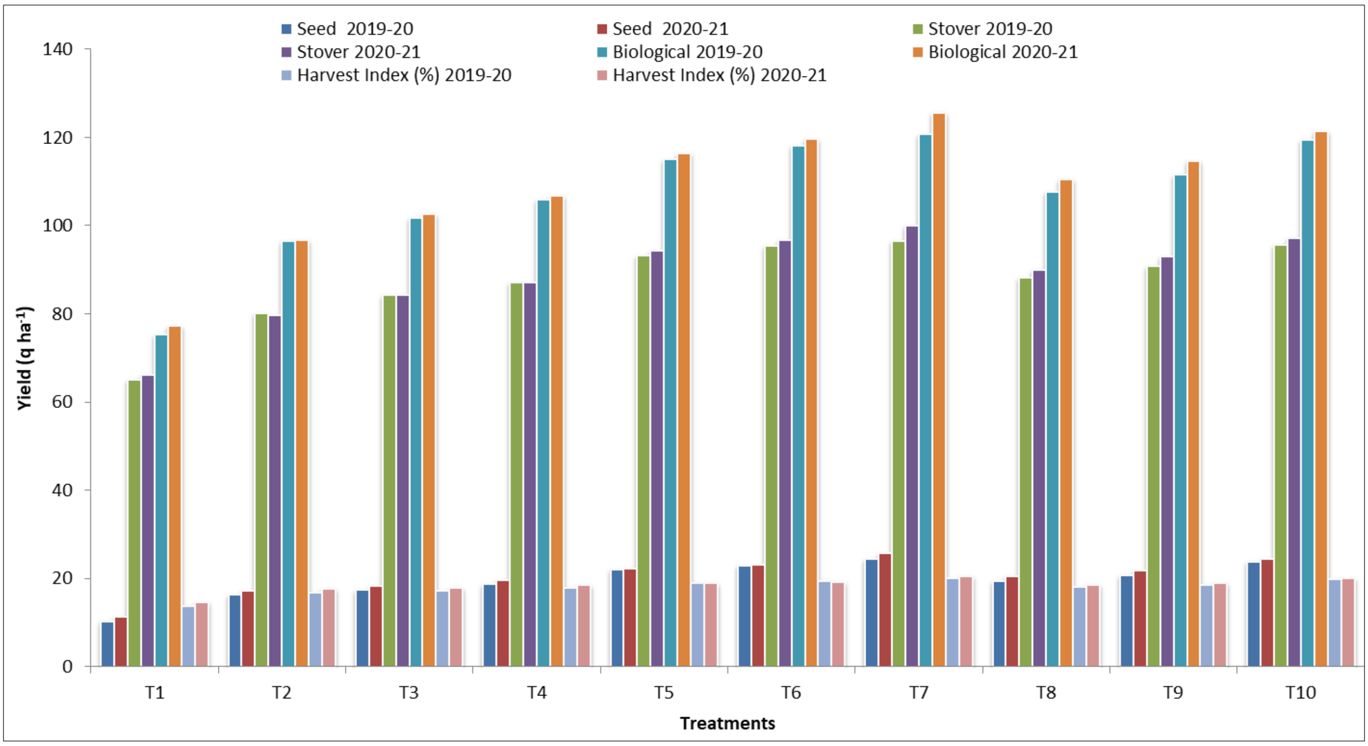

Fig 2: Effect of integrated nutrient management on biological, seed, stover yield (q ha^{-1}) and harvest index (%) of mustard

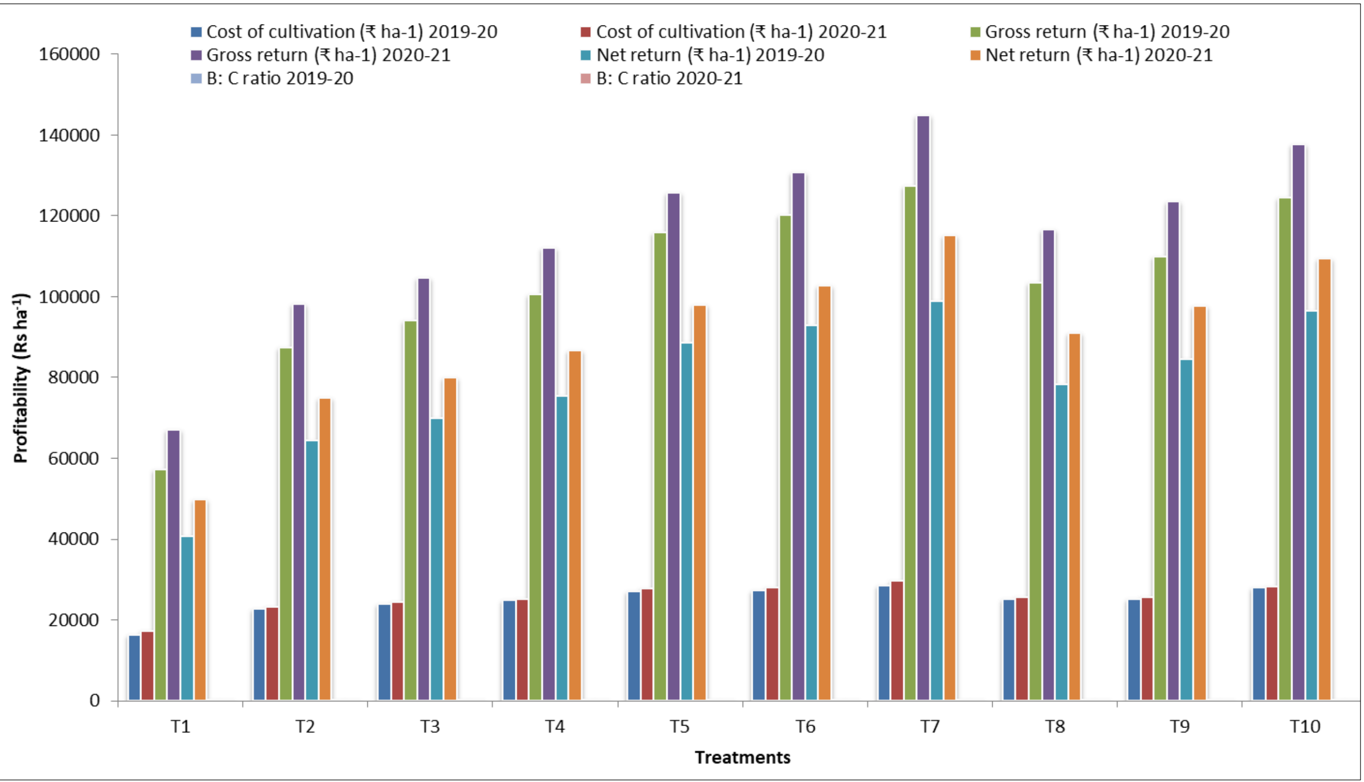

Fig 3: Effect of integrated nutrient management on economics of mustard

Conclusion

All the growth, yield attributes and yield of mustard improved with the application of organic and inorganic fertilizers and achieved maximum value with 100% RDF (-S) + 2 ton FYM + 0.6 ton Vermicompost. Application of micronutrients not only improves the content of Zn in grain and straw but also improve the content of N, P, K, S and Fe. A common fertilizer dose of RDF with micronutrients able to maintain the soil fertility while improving the micronutrients availability in soil. It is obvious that cost of cultivation increased by the additional input of micronutrients but the ultimate net return and B:C ratio was maximum with application 100% RDF (-S) + 2 ton FYM + 0.6 ton Vermicompost followed by 75% RDF + 2 ton FYM + 0.6 ton Vermicompost (T_{10}) and 100% RDF (-S) + 1.25 ton Vermicompost (T_6) during both the years.

Acknowledgements

This study has been executed at the Crop research centre of Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut, Uttar Pradesh, India under the Department of Soil Science & Agricultural Chemistry during *rabi* 2019 & 2020. I would like to thank the Department of Soil Science & Agricultural Chemistry for offering me the necessary facilities during this period.

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