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Effects of bio-organics and micronutrients on yield and nutrient uptake by mustard on loamy-sand soil of Rajasthan

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Abstract

A field experiment was conducted under loamy sand soil during two consecutive *rabi* seasons at Agronomy Farm, S.K.N. of College of Agriculture, Jobner, India. The experiment comprising 20 treatments combination replicated three times, was laid out in the split-plot design with five treatments of bio-organic (control, FYM @ 10 t/ha, vermicompost @ 5 t/ha, FYM @ 10 t/ha + *Azotobacter* + VAM and vermicompost @ 5 t/ha + *Azotobacter* + VAM) and four treatments of micronutrients (Control, $ZnSO_4$ @ 25 kg/ha, $FeSO_4$ @ 50 kg/ha and $ZnSO_4$ @ 25 kg/ha + $FeSO_4$ @ 50 kg/ha). The significantly highest seed and stover yields, nutrients (N, P, K, S, Zn & Fe) content as well as uptake by mustard over control were recorded with the application of vermicompost @ 5 t/ha + *Azotobacter* + VAM. The application of $ZnSO_4$ @ 25 kg/ha + $FeSO_4$ @ 50 kg/ha registered significantly highest seed and stover yields, nutrients (N, K, S, Zn & Fe) content and Nutrient (N, P, K, S, Zn & Fe) uptake in seed & stover over rest of the treatments. Whereas, phosphorus concentration in both seed and stover decreased significantly with application of M3 ($ZuSO_4$ @ 25 kg/ha + $FeSO_4$ @ 50 kg/ha). Based on the experimental results, it is concluded that for substantial improvement in yields and nutrients (N, P, K, S, Zn & Fe) content as well as uptake by mustard individual and conjoint application of the treatment vermicompost @ 5 t/ha + *Azotobactor* + VAM (B_4) and $ZnSO_4$ @ 25 kg/ha + $FeSO_4$ @ 50 kg/ha(M_3) is required.

Keyword : *Azotobacter*, FYM, Mustard, Nutrient, VAM, Vermicompost and Yield

Introduction

Indian mustard [*Brassica juncea* (L.) Czern and Coss] is one of the important edible oilseed crop of India next to groundnut and soybean. The seed and oil are used as condiment in the preparation of pickles, flavoring of curries and vegetables. The oil is utilized for human consumption throughout northern India in cooking and frying purposes. It is also used in the preparation of hair oils, medicines, soap making, mixtures with mineral oils for lubrication and manufacture of greases. The oil cake is used as a cattle feed and manures.

There is a great scope for increasing the production of mustard by bringing more area under cultivation and its productivity by applying organic manures (FYM and vermicompost) with balanced fertilization and maintaining soil fertility status. The increased use of chemical fertilizers in agriculture has certainly enhanced the food production but it has brought with it a host of problems related to micronutrient deficiency and environmental pollution. Integrated use of chemical fertilizers with organic manures could be quite promising in maintaining higher productivity and providing greater stability in crop production.

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Among the organic manures, farm yard manure (FYM) is one of the most readily available traditional source and widely used by the farmers since time immemorial. Addition of organic material to the soil such as FYM helps in maintaining soil fertility and productivity. It increases soil microbiological activities, plays key role in transformation, recycling and availability of nutrients to the crop (Collins *et al.* 1992). Vermicompost has been advocated as good organic manure for use in the field crops. Earthworm-processed organic waste often referred to as vermicompost is peat like materials with high porosity, aeration, drainability and water holding capacity. They contain nutrients in the readily available form to the plants such as nitrate, exchangeable phosphorus, soluble K, Ca and Mg (Edwards and Burrows, 1988). They also contain biologically active substances such as plant growth regulators, vitamins and acts as powerful biocide against diseases and nematodes. Poor nutrient economy of light textured soils necessitates the need for supplementing fertilizer with organic manures (Tomati *et al*., 1987).

For sustainable crop production, conjunctive use of organic, inorganic and bio-fertilizers is very essential. Bio-fertilizers along with organic manures play an important role in sustainable agriculture. A number of micro-organisms including nitrogen fixing bacteria *i.e. Azotobacter* and *Azospirillum* have been used as bio-fertilizers to increase availability of nitrogen. Role of these bio-fertilizers in fixing nitrogen is well established. Besides, these micro-organisms secrete phytohormones and build-up the soil fertility. Mycorrhizae colonize the root cortex (affect root morphology and keep the roots functional for a longer period) to obtain carbon from host plant while assisting the plant with rapid uptake of phosphorus along with other mineral nutrients of low mobility from the soil (by extending hyphae) and their translocation to host root. Mycorrhizae also produce siderophores which chelate Fe and release P for plant availability and phosphatases which mobilize organic P compounds. Influence of combined inoculation of PSM and mycorrhizae is synergestic for many crops.

Recent soil and foliage tests indicates a wide spread deficiency of Zn particularly in the light textured soils, having low organic carbon and alkaline reaction. In many parts of country zinc is a plant nutrient now stands third in importance next to nitrogen and phosphorus (Takkar and Randhawa, 1978). Therefore, micronutrients are considered as one of the constraints in the optimum production of crops. Zinc being one of the essential micronutrient, plays significant role in various enzymatic and physiological activity of the plant body. It is also essential for photosynthesis and nitrogen metabolism. It promotes synthesis of growth hormone, seed maturation, starch synthesis, chlorophyll synthesis and regulates water absorption. It is an important element for the stability of cytoplasmic ribosomes, cell division, dehydrogenase, proteinase and peptidase enzymes and also help in the synthesis of protein and carotene. Iron is a structural component of porphyrin molecules, cytochromes, heams, hematin, ferrichrome and leghaemoglobin. These substances are involved in oxidation-reduction reactions in respiration and photosynthesis. It is also an important part of the enzyme nitrogenase, which is essential for nitrogen fixation. Iron in chloroplasts reflects the presence of cytochromes for performing various photosynthetic reduction processes and of ferrodoxin as an electron acceptor. The ferrodoxins are Fe-S proteins and are the first stable redox compound of the photosynthetic electron transport chain (Havlin *et al*., 1997).

Materials and Methods

A field experiment was carried out during the winter (*rabi*) seasons at S.K.N. College of Agriculture, Jobner (26^0 05′ North, longitude of 75^0 28′ East and at an altitude of 427 metres above mean sea level), Rajasthan.The soil was sandy loamy sand having with bulk density as 1.52 Mg/m^3 and pH 8.3. The soil was poor in organic carbon (0.23%), low available nitrogen (130.5 kg/ha) and phosphorus (15.1 kg/ha) and medium in potassium (148.9 kg/ha). The experiment was laid out in split-plot design with three replications. The treatments comprising five bio-organics i.e. B_0 (Control), B_1 (FYM @ 10 t/ha), B_2 (Vermicompost @ 5 t/ha), B_3 (FYM @ 10 t/ha + *Azotobactor* + VAM) and B_4 (Vermicompost @ 5 t/ha + *Azotobactor* + VAM) and four micro nutrients i.e. M_0 (Control), M_1 (zinc sulphate @ 25 kg/ha), M_2 (ferrous sulphate @ 50 kg/ha) and M_3 (zinc sulphate @ 25 kg/ha + ferrous sulphate @ 50 kg/ha). Mustard variety "Bio-902" was sown on 1st November and 18th October during 2013 and 2014, respectively. Seed @ 4 kg/ha was taken with 30 cm row spacing.

Vermicompost was applied as per treatment just before sowing. The weighed quantity of well decomposed farm yard manure (FYM) was applied as per treatments at 20 days before sowing and incorporated well in surface soil layer manually. A 10-15 g of jaggery was boiled in 100 ml of water and then cooled and 50 g of culture was mixed in jaggery solution. The required quantity of seed was thoroughly mixed with the paste of culture to inoculate them with *Azotobacter* and then the seeds were allowed to dry in shade before sowing. The soil based VAM inoculation (*Glomus fasciculatum*) containing hyphae, spores, sporocarp and infected root fragments were applied to the open furrows @ 15 kg/ha (13-15 viable spore/g inoculums) using field soil to bulk the carrier in a uniform layer at a depth of about 5 cm. Zinc and iron was applied basally through $ZnSO_4.7H_2O$ and $FeSO_4.7H_2O$ as per treatment at sowing time according to the plan of layout and incorporated in soil. The S supplied through $ZnSO_4$ and $FeSO_4$ equated by elemental sulphur to meet out the 40 kg S/ha uniformly and elemental sulphur was applied 20 days before sowing. Half dose of N and full dose P and K was applied as basal before sowing and remaining half dose of N was top dressed in two splits i.e. after Ist and IInd irrigation. Three irrigations were given to the crop at 35, 65 and 90 DAS by check basin method. The crop was harvested from a net plot size of 3.0 m x 1.8 m (5.4 m^2) separately, tied in bundles and after tagging these were left on the threshing floor for sun drying. After complete drying, bundles were weighed to record biological yields. Thereafter, threshing was done by beating the plants with sticks. The seed and stover were separated by manual winnowing and yield was recorded in q/ha.

All the observation during individual years as well as in pooled analysis was statistically analyzed for their test of significance using the *F*-test. The significant difference between treatment means were compared with t critical difference at 5 % level of probability.

Results and Discussion

Yields

Effect of bio-organics

The application of vermicompost @ 5 t/ha + *Azotobacter* + VAM (B_4) recorded significantly highest seed and stover yields (Table 1) over control (B_0). Significant increase in growth of plant under conjoint application of vermicompost and FYM may be attributed to the better availability

Table 1. Effect of bio-organics and micronutrients (Zn & Fe) application on seed and stover yields of mustard

Treatments	Seed yield (kg/ha)	Stover yield (kg/ha)
Bio-organics		
B_0: Control	723	2273
B_1: FYM @ 10 t/ha	1205	3338
B_2: VC @ 5 t/ha	1498	3750
B_3: FYM @ 10 t/ha + Azoto.+VAM	1703	4114
B_4: VC @ 5 t/ha + Azoto.+VAM	1861	4403
SEm±	30	51
CD (P = 0.05)	87	150
Micronutrients (Zn & Fe)		
M_0: Control	930	2720
M_1: $ZnSO_4$ @ 25 kg/ha	1497	3752
M_2: $FeSO_4$ @ 50 kg/ha	1450	3710
M_3: $ZnSO_4$ @ 25 kg/ha + $FeSO_4$ @ 50 kg/ha	1716	4121
SEm±	21	36
CD (P = 0.05)	59	100

FYM = Farm yard manure, VC = Vermicompost, Azoto = Azotobacter, VAM = Vesicular arbuscular mycorrhiza of nutrients in balanced form throughout the life cycle of the crop, effective utilization of nutrients, besides increasing microbial activity by supplying substrates to the soil available microorganisms which are responsible for mineralization of soil native status of the nutrients (Tripathi *et al.*, 2011). The ability of *Azotobactor* to produce growth substances and antifungal substances in addition to fixed N made available to plants was probably the reason of higher yields of seed and stover of the crop (Singh *et al.,* 2014). The enhanced availability of phosphate to the crop plants during the growth period may also be due to solubilisation, mineralization of soil native phosphate and potassium which might have also in turned in to higher yield potentials. The increase in seed yield due to application of vermicompost and FYM may also be due to the fact that application of vermicompost and FYM favourably improved the nutritional environment along with soil physical condition of the soil (Jat *et al.,* 2013) there by resulting in better growth and development leading to higher yield attributes and yield of seed and stover of the crop (Yadav *et al.*, 2013, Sipai *et al.*, 2017 and Kumar *et al.* 2018).

Effect of micronutrients

The application of Zn and Fe micronutrients individually or in combination significantly influenced the seed and stover yields of mustard (Table 1). The application of both micronutrients in combination ($ZnSO_4$ @ 25 kg/ha + $FeSO_4$ @ 50 kg/ha) obtained significantly higher seed and stover yields over control (Table 1). The higher fertility level of the soil might have improved the growth and development of the plants by improving the uptake of essential nutrients and translocation of sink to source and better accumulation of dry matter right from the early stage of crop growth to harvest by virtue of increased photosynthetic efficiency under this treatment (Kumar and Ahlawat, 2008., Jadhav *et al.* 2009., Baber and Dongale, 2013).

Nutrient content

Effect of bio-organics

The application of various bio-organics significantly enhanced the N, P, K, S, Zn and Fe

Table 2. Effect of bio-organics and micronutrients (Zn & Fe) application on nutrient content in seed and stover of mustard

Treatments	Nutrient content (%)											
	Nitrogen		Phosphorus		Potassium		Sulphur		Zinc (mg/kg)		Iron (mg/kg)	
	Seed	Stover	Seed	Stover	Seed	Stover	Seed	Stover	Seed	Stover	Seed	Stover
Bio-organics												
B_0: Control	2.928	0.595	0.510	0.160	0.554	1.084	0.799	0.402	30.65	21.76	140.33	150.13
B_1: FYM @ 10 t/ha	3.166	0.643	0.556	0.179	0.617	1.148	0.848	0.434	33.09	23.95	149.85	159.38
B_2: VC @ 5 t/ha	3.339	0.663	0.573	0.189	0.655	1.171	0.885	0.459	34.59	25.44	156.17	165.65
B_3: FYM @ 10 t/ha + Azoto. + VAM	3.503	0.680	0.589	0.197	0.681	1.189	0.920	0.483	36.05	26.89	161.92	171.46
B_4: VC @ 5 t/ha + Azoto. + VAM	3.657	0.696	0.604	0.205	0.703	1.205	0.955	0.506	37.48	28.33	167.40	177.25
SEm±	0.034	0.004	0.003	0.002	0.004	0.004	0.008	0.005	0.31	0.31	1.20	1.27
CD (P = 0.05)	0.099	0.011	0.010	0.005	0.011	0.010	0.023	0.014	0.92	0.93	3.55	3.74
Micronutrients (Zn & Fe)												
M_0:Control	3.070	0.611	0.602	0.203	0.590	1.103	0.833	0.426	32.61	24.26	148.88	158.75
M_1:$ZnSO_4$ @ 25 kg/ha	3.430	0.676	0.567	0.187	0.638	1.157	0.880	0.453	34.75	25.49	153.25	162.75
M_2:$FeSO_4$ @ 50 kg/ha	3.300	0.652	0.554	0.180	0.646	1.164	0.903	0.472	34.38	25.11	158.12	167.98
M_3: $ZnSO_4$ @ 25 kg/ha + $FeSO_4$ @ 50 kg/ha	3.475	0.684	0.544	0.175	0.695	1.214	0.911	0.476	35.77	26.25	160.29	169.63
SEm±	0.027	0.005	0.004	0.004	0.003	0.004	0.008	0.005	0.29	0.29	0.89	1.02
CD (P = 0.05)	0.075	0.013	0.012	0.010	0.009	0.013	0.021	0.014	0.81	0.80	2.49	2.85

FYM = Farm yard manure, VC = Vermicompost, Azoto = Azotobacter, VAM = Vesicular arbuscular mycorrhiza content in seed and stover of mustard (Table 2). The application of vermicompost @ 5 t/ha + *Azotobacter* + VAM (B_4) recorded significantly higher, P, K, S, Zn and Fe content both in seed and stover of mustard. The positive influence of bio organic on nutrient content of the crop appears to be on account of the favourable nutritional environment both in the crop root zone and the plant system leading to enhanced translocation in plant parts (Sharma *et al*., 2014). The higher content of N of vermicompost along with growth hormones might have helped in better absorption and utilization of all the plant nutrients, thus resulting in more N, P, K, S, Zn and Fe content in seed and stover of the crop (Ola *et al*., 2013). The increase in nutrients concentration in seed and stover of the plant with the application of vermicompost + FYM + PSB + *Azotobactor* might be due to increased availability of nutrients to plants due to gradual mineralization along with increased moisture holding capacity and improving the physical condition of the soil (Jat *et al*., 2013). Organic matter also function as source of energy for soil microflora which bring about the transformation of inorganic nutrients held in soil in the form that are readily utilized by growing plants. The enhanced microbial activity under organic nutrition along with multistrains inoculants might have also generated favourable soil environment for better nutrient supplementation (Nayak *et al*., 2006).

Effect of micronutrients

The application of micronutrients significantly influenced the N, K, S, Zn and Fe content in seed and stover over control (Table 2). The application of $ZnSO_4$@ 25 kg/ha + $FeSO_4$ @ 50 kg/ha (M_3) brought significantly higher N, K, S, Zn and Fe content in seed and stover over control (M_0). The treatment M_3 has also found statistically at par with the treatment M_2. Whereas phosphorus content in both seed and stover decreased significantly with application of M_3 ($ZnSO_4$ @ 25 kg/ha + $FeSO_4$ @ 50 kg/ha. The increased content of nutrients in seed and stover of the crop with the application of M_3 ($ZnSO_4$ @ 25 kg/ha + $FeSO_4$ @ 50 kg/ha) might be due to improved nutritional environment in the rhizosphere as well as in the plant system, which might have lead to enhanced translocation of nutrients in plant parts (Sharma *et al*., 2014). It is owing to the fact that experimental soil was deficient in these nutrients, the increase in N, K, S, Zn and Fe concentration seems to be associated with increased availability (Kumawat and Aswal, 2005 and Jat *et al*., 2013) coupled with increased metabolic activity at cellular level might have increased their accumulation in seed and stover of the crop. Release of nutrients in available form and other physical properties might have influenced the availability of other nutrients leading to their adsorption. There by showing a higher content with the application of Zn and Fe (Jat and Mehra, 2007). Similar findings are noted by Piri and Sharma (2006) and Pachauri *et al*. (2012).

Nutrients uptake

Effect of Bio organics

The application of different bio-organics significantly influenced the N, P, K, Zn and Fe uptake by seed and stover (Table 3). The significantly higher N, P, K, Zn and Fe uptake of seed and stover were recorded with the application of vermicompost @ 5 t/ha + *Azotobacter* + VAM (B_4) higher over control (B_0).The increased uptake with the conjoint application of vermicompost, FYM and Azotobactor might be due to increased availability of nutrients in balanced form in to plants throughout the growth period of the crop (Ola *et. al*, 2013) and improved physical and chemical environment of the soil might have helped in vigorous growth of the plant and root proliferation, and the increased biomass production resulted in higher uptake of the nutrients (Tripathi *et al*., 2010). Although, nutrient use efficiency was very low because the experimental soil was light textured (Loamy sand). Since nutrient uptake by crop is a function primarily of dry matter accumulation and nutrient concentration at cellular level. The increased photosynthetic efficiency leading to increased dry matter production and higher nutrient concentration in seed and stover to be responsible for N, P, K, S, Zn and Fe uptake under the influence of vermicompost/FYM along with PSB and *Azotobactor* (Ola *et al*., 2013). The higher values of uptake might also be due to improved inherent nutrient supplying capacity of nutrients, complexing of nutrients particularly of

Table 3. Effect of bio-organics and micronutrients (Zn & Fe) application on nutrients uptake by mustard

Treatments	Nitrogen (kg/ha)		Phosphorus (kg/ha)		Potassium (kg/ha)		Sulphur (kg/ha)		Zinc (g/kg)		Iron (g/ha)	
	Seed	Stover	Seed	Stover	Seed	Stover	Seed	Stover	Seed	Stover	Seed	Stover
Bio-organics												
B_0: Control	21.36	13.61	3.66	3.61	4.05	24.75	5.81	9.19	223.05	496.52	101.94	342.36
B_1: FYM @ 10 t/ha	38.52	21.60	6.65	5.94	7.52	38.53	10.30	14.58	401.48	802.63	181.52	533.81
B_2: VC @ 5 t/ha	50.51	25.01	8.52	7.02	9.92	44.13	13.35	17.33	521.86	957.58	235.24	623.33
B_3: FYM @ 10 t/ha + Azoto. + VAM	60.20	28.16	9.95	8.05	11.74	49.15	15.78	19.99	618.03	1110.69	277.15	707.97
B_4: VC @ 5 t/ha + Azoto. + VAM	68.70	30.84	11.16	8.98	13.24	53.29	17.89	22.43	702.09	1252.27	313.13	783.28
SEm±	0.96	0.43	0.15	0.13	0.23	0.83	0.24	0.31	9.79	17.16	5.52	16.52
CD (P = 0.05)	2.84	1.27	0.45	0.38	0.68	2.44	0.70	0.90	28.88	50.63	16.28	48.73
Micronutrients (Zn & Fe)												
M_0: Control	29.16	16.81	5.68	5.62	5.61	30.23	7.88	11.79	309.04	671.92	140.80	436.95
M_1: $ZnSO_4$ @ 25 kg/ha	52.45	25.65	8.62	7.14	9.77	43.74	13.40	17.26	530.22	973.88	233.33	617.88
M_2: $FeSO_4$ @ 50 kg/ha	48.89	24.46	8.16	6.79	9.59	43.50	13.31	17.81	508.14	948.60	233.19	630.56
M_3: $ZnSO_4$ @ 25 kg/ha + $FeSO_4$ @ 50 kg/ha	60.94	28.48	9.48	7.32	12.21	50.41	15.91	19.95	625.81	1101.35	279.86	707.21
SEm±	0.79	0.37	0.13	0.11	0.18	0.54	0.20	0.26	8.04	14.49	3.71	10.82
CD (P = 0.05)	2.20	1.05	0.36	0.30	0.51	1.52	0.55	0.72	22.50	40.58	10.38	30.31

FYM = Farm yard manure, VC = Vermicompost, Azoto = Azotobacter, VAM = Vesicular arbuscular mycorrhiza

micronutrients, flush of available nutrients on autolysis of microbial cells besides improvement in biometric parameters (Gour *et al*., 2017 and Jain *et al*., 2018).

Effect of Micronutrients

The highest uptake of N, P, K, S, Zn and Fe by seed and stover were recorded with the application of treatment M_3 ($ZnSO_4$ @ 25 kg/ha + $FeSO_4$ @ 50 kg/ha) over control (Table 3). The increase in uptake of N, P, K, S, Zn and Fe seems to be associated with increased availability with a concomitant increase in crop yield with treatment M_3 ($ZnSO_4$ @ 25 kg/ha + $FeSO_4$ @ 50 kg/ha) application (Jat *et al*., 2013). The increase in uptake of N, P, K, S, Zn and Fe attributed to the application of M_3 ($ZnSO_4$ @ 25 kg/ha + $FeSO_4$ @ 50 kg/ha) might be due to vigorous root and shoot growth resulting in greater absorption of the nutrients from the soil, favourable influence on photosynthates and metabolic process which augments the production of photosynthates and their translocation to different plant parts including seed and stover, and ultimately increased the uptake of N, P, K, S, Zn and Fe by seed and stover (Upadhyay, 2012).

Conclusion

Based on the experimental results of two year it is concluded that for substantial improvement in yield and nutrients (N, K, S, Zn & Fe) content as well as uptake (N, P, K, S, Zn & Fe) by mustard individual and conjoint application of the treatment vermicompost @ 5 t ha^{-1} + *Azotobactor* + VAM (B_4) and $ZnSO_4$ @ 25 kg ha^{-1} + $FeSO_4$ @ 50 kg ha^{-1} (M_3) is required.

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