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Computation of correlations of fortified vermicompost with sulphur on seed yield and nutrient content of mustard [*Brassica juncea*]

Suman Parihar[1*], P. R. Kameriya[2] and Rakesh Choudhary[3]

[1]Department of Soil Science and Agricultural Chemistry, Sri Karan Nerandra Agricultural University, Jobner-303329 (Rajasthan), INDIA
[2]Department of Soil Science and Agricultural Chemistry, College of Agriculture, Bikaner-334006 (Rajasthan), INDIA
[3]Subject Matter Specialist (Agronomy), Krishi Vigyan Kendra, Ambala (Haryana), INDIA
[*]Corresponding author. E-mail: pariharsuman30@gmail.com

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Abstract: Effect of sulphur and fortified vermicompost on growth and yield of mustard [*Brassica juncea*] was carried out at College of Agriculture, Swami Keshwanand Rajasthan Agricultural University, Bikaner (Rajasthan) during *rabi* season: 2010-11. Sixteen treatment combinations comprising four levels of each sulphur and fortified vermicompost were evaluated. Grain yield (1993 kg ha^{-1}) increased significantly ($p < 0.05$) up to 6.0 t vermicompost ha^{-1} along with 40 kg sulphur ha^{-1}. As regards interactive effects of treatment, synergistic behavior was noted between 6.0 t vermicompost ha^{-1} 40 kg S ha^{-1} for seed yield, nitrogen, and phosphorus contents and also sulphur content and uptake by seed of mustard. The significantly higher P content in seed was recorded under 40 kg S ha^{-1} in combination with 4.0 t ha^{-1} vermicompost Combined effect of levels of vermicompost and sulphur on seed yield was found to be significant than control. The concomitant effect of 6.0 t vermicompost ha^{-1} and 40 kg S ha^{-1} application was found highly pronounced on seed yield and sulphur content in seed of mustard.

Keywords: Computation, Nutrient content, Sulphur uptake, Vermicompost, Yield

INTRODUCTION

Mustard [*Brassica juncea* (L) Czern and Coss] is the second most important oilseed crop in India next to groundnut. India is the third largest producer of rapeseed-mustard (Piri *et al.,* 2011) having 5.90 million hectares area with 6.41 million tonnes production, but the average yield of rapeseed-mustard in India is only 1145 kg/ha (Economic survey, 2013). The sulphur requirement of oilseed crops is known to be high and increase in the production of mustard due to the application of sulphur have been reported by Aulakh *et al.* (1977). Application of sulphur was reported to increase yield attributes and yield of Indian mustard (Patel *et al.* 2009, Kumar *et al.,* 2011), which also has a significant effect on oil, fatty acid (Ahmad and Abdin 2000) and glucosinolates content in mustard seed (Falk *et al.,* 2007). The relative proportions of individual glucosinolates viz. sinigrin (allyl isothio-cyanate), gluconapin (3-butenyl glucosinolate) and progoitrin (2-hydroxy-3-butenyl glucosinolate) are influenced by sulphur application (Hassan *et al.,* 2007).

Balance fertilization through organic and inorganic sources collectively improves the yield and soil health. Incorporation of organic residues directly or indirectly also improves the physical properties of soil and helps in sustaining the crop production (Swarup and Wanjari, 2000). A field experiment conducted to find out the effect of organic manure fortified with micronutrients *viz.,* $ZnSO_4$ and $FeSO_4$ on the growth and yield of rice in coastal saline soil showed that, micronutrients fortified composted green leaf manure significantly increased the growth and yield parameters of rice as compared to other treatments Kamaraj *et. al.* (2010). Sulphur being a component of amino acids is involved in the quality and productivity of mustard. The present study was therefore conducted to study the response of vermicompost and sulphur on the growth and yield of mustard [*Brassica juncea*].

MATERIALS AND METHODS

A field experiment was conducted at the Agronomy farm of college of Agriculture, Bikaner during *Rabi* of 2010 using mustard cv. Bio-902 (Pusa Jai Kisan) as the test crop. The experimental soil was loamy sand, low in available N, P, K and S (113, 20, 114 kg ha^{-1} and 8.5 mg kg^{-1}, respectively). The soil was non saline with a reaction 8.5 and low organic carbon (0.13%). Treatments consisted of 16 combinations i.e. four levels of fortified vermicompost, namely control (V_0), 2(V_2), 4 (V_4), and 6(V_6) t ha^{-1} and four levels of sulphur viz. control (S_0), 20(S_{20}), 40(S_{40}) and 60(S_{60}) kg ha^{-1} were replicated thrice and laid out in RBD. As per treatments, elemental sulphur and vermicompost were applied prior

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to sowing and recommended dose of nitrogen @ 90 kg ha $^{-1}$ and phosphorus @ 40 kg ha^{-1} were applied as per treatment through Urea and DAP. Grain and stover yields were recorded at harvest, plant samples were analyzed using standard procedure (Snell and Snell, 1971; Jackson, 1967; Tabatabai and Bremmer, 1970) for N, P and S, respectively. All agronomic practices were carried out uniformly for all treatments. After threshing and winnowing, the clean seeds obtained from the produce of individual plot were weighed and weight was recorded as seed yield kg/ plot. Later, this was converted into q ha^{-1}.The uptake of nitrogen, phosphorus, potassium and sulphur at harvest in seed and stover were estimated by using the following formula:

$$\text{Nutrient uptake (kg ha}^{-1}\text{)} = \frac{\text{Per cent nutrient content in seed} \times \text{Seed yield (kg ha}^{-1}\text{)} + \text{Per cent nutrient content in straw} \times \text{Straw yield (kg ha}^{-1}\text{)}}{100}$$

For estimation of nutrient content representative samples of seed and stover were taken at the time of threshing. Each dried seed and stover samples were ground to fine powder in an electric grinder. Nitrogen, phosphorus, potassium and sulphur in seed and stover were estimated by using standard methods given in Table 1.

RESULTS

Seed yield

Effect of vermicompost: The seed yield increased significantly with increasing levels of fortified vermicompost (Table 7). The maximum seed yield (1865.0 kg ha^{-1}) was observed under the treatment $V_{6.0}$ while

Table1: Methods for plant analysis.

S. No	Determination	Methods	References
1	Digestion of plant samples-I	Wet digestion of plant samples with H_2SO_4 and H_2O_2	Jackson (1967)
2	Nitrogen content	N was estimated by colorimetric method on spectronic-20 after development of colour with Nesseler's reagent	Snell and Snell (1939)
3	Digestion of plant samples-II	Wet digestion of plant samples with di-acid mixture as per the method described	Johnson and Ulrich (1959)
4	Phosphorus content	Phosphorus was estimated on spectronic-20 by using Vando-molybdo phosphoric yellow colour method in nitric acid system	Jackson (1967)
5	Sulphur content	By colorimeteric measurement method	Tabatabai and Bremmer (1970)

Mean weekly meteorological data for crop season (*rabi*, 2010) were optimum for potential crop growth and production (Fig.1).

Table 2: Interaction effect between vermicompost and sulphur on seed yield of mustard.

Sulphur levels (kg S ha^{-1})	Vermicompost levels (t ha^{-1})				
	Control (V_0)	2.0 (V_2)	4.0 (V_4)	6.0 (V_6)	Mean
Control (S_0)	956	1151	1458	1589	1289
20 (S_{20})	980	1369	1658	1862	1467
40 (S_{40})	1107	1495	1796	1993	1598
60 (S_{60})	1108	1496	1817	2016	1610
Mean	1038	1378	1682	1865	
	V	S	VXS		
S.Em±	17.4	17.4	34.8		
CD (5%)	50.3	50.3	100.6		

Table 3: Interaction effect between vermicompost and sulphur on N content in seed of mustard.

Sulphur leves (kg S ha^{-1})	Vermicompost levels (t ha^{-1})				
	Control (V_0)	2.0 (V_2)	4.0 (V_4)	6.0 (V_6)	Mean
Control (S_0)	2.21	3.06	3.37	3.73	3.09
20 (S_{20})	3.14	3.43	3.78	4.07	3.60
40 (S_{40})	3.47	3.76	4.09	4.42	3.93
60 (S_{60})	3.48	3.79	4.11	4.44	3.96
Mean	3.07	3.51	3.84	4.17	-
S.Em±	0.09	-	-	-	-
CD (5%)	0.25	-	-	-	--

Table 4: Interaction effect between vermicompost and sulphur on P content in seed of mustard.

Sulphur levels (kg S ha^{-1})	Vermicompost levels (t ha^{-1})				
	Control (V_0)	2.0 (V_2)	4.0 (V_4)	6.0 (V_6)	Mean
Control (S_0)	0.471	0.676	0.754	0.835	0.684
20 (S_{20})	0.691	0.767	0.843	0.910	0.803
40 (S_{40})	0.773	0.843	0.921	0.982	0.880
60 (S_{60})	0.775	0.847	0.923	0.988	0.883
Mean	0.677	0.783	0.860	0.929	-
S.Em±	0.023	-	-	-	-
CD (5%)	0.065	-	-	-	

Table 5: Interaction effect between vermicompost and sulphur on sulphur content in seed of mustard.

Sulphur levels (kg S ha^{-1})	Vermicompost levels (t ha^{-1})				
	Control (V_0)	2.0 (V_2)	4.0 (V_4)	6.0 (V_6)	Mean
Control (S_0)	0.453	0.770	0.938	1.018	0.795
20 (S_{20})	0.687	0.854	0.993	1.107	0.910
40 (S_{40})	0.766	0.925	1.070	1.202	0.991
60 (S_{60})	0.780	0.933	1.077	1.205	0.999
Mean	0.672	0.871	1.019	1.133	
S.Em±	0.026				
CD (5%)	0.075				

Table 6: Interaction effect between vermicompost and sulphur on sulphur uptake by seed of mustard.

Sulphur levels (kg S ha^{-1})	Vermicompost levels (t ha^{-1})				
	Con-trol (V_0)	2.0 (V_2)	4.0 (V_4)	6.0 (V_6)	Mea n
Control (S_0)	4.34	8.86	13.67	16.17	4.34
20 (S_{20})	6.74	11.69	16.46	20.61	6.74
40 (S_{40})	8.48	13.81	19.22	23.94	8.48
60 (S_{60})	8.64	13.96	19.56	24.32	8.64
Mean	7.05	12.08	17.23	21.26	7.05
S.Em±	0.47	-	-	-	0.47
CD (5%)	1.35	-	-	-	1.35

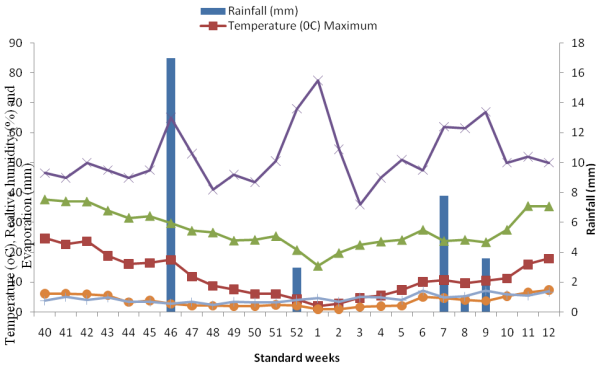

Fig.1. *Mean weekly meteorological data during crop season Rabi, 2010-11. (Agricultural Research Station, Beechwal, Bikaner).*

Table 7 : Effect of fortified vermicompost and sulphur levels on seed yield, nitrogen, phosphorus, sulphur (N, P&S) content and sulphur uptake of mustard.

Treatments	Seed Yield (kg ha^{-1})	N content %	P content %	S content %	S uptake kg ha^{-1}
Vermicompost levels (t ha^{-1})					
(i) Control	1037.92	3.07	0.677	0.672	7.05
(ii) 2.0	1377.92	3.51	0.783	0.871	12.08
(iii) 4.0	1682.25	3.84	0.860	1.019	17.23
(iv) 6.0	1865.00	4.17	0.929	1.133	21.26
S.Em±	17.41	0.04	0.011	0.013	0.23
CD (5%)	50.29	0.12	0.033	0.038	0.68
Sulphur levels (kg S ha^{-1})					
(i) Control	1288.50	3.09	0.684	0.795	10.76
(ii) 20	1467.08	3.60	0.803	0.910	13.87
(iii) 40	1598.00	3.93	0.880	0.991	16.36
(iv) 60	1609.50	3.96	0.883	0.999	16.62
S.Em±	17.41	0.04	0.011	0.013	0.23
CD (5%)	50.29	0.12	0.033	0.038	0.68

the minimum (1037.92 kg ha^{-1}) under control (V_0). The increase in seed yield was obtained to the extent of 32.75, 62.07 and 79.68 per cent with the application of fortified vermicompost @ 2.0, 4.0 and 6.0 t ha^{-1}, respectively as compared to control.

Effect of sulphur: The application of sulphur significantly increased the seed yield over control. The maximum seed yield (1609.50 kg ha^{-1}) of mustard was recorded under treatment S_{60}. However, seed yield obtained with treatments S_{40} and S_{60} was at par. The treatments S_{20}, S_{40} and S_{60} increased the yield to the extent of 13.85, 24.02 and 24.91 per cent, respectively as compared to control (S_0).

Interaction effect between vermicompost and sulphur on seed yield of mustard: Combined effect of levels of vermicompost and sulphur on seed yield was found to be significant (Table 2). Significantly higher seed yield was recorded with 6.0 t ha^{-1} fortified vermicompost in combination with 40 kg S ha^{-1} (Table2). Minimum seed yield was recorded under control.

Nitrogen content

Effect of vermicompost: The nitrogen content in seed and stover increased significantly with increasing levels of fortified vermicompost. The maximum nitrogen content in seed (4.17%) was found under the treatment $V_{6.0}$ and the minimum (3.07%) nitrogen content was recorded under V_0. The application of fortified vermicompost @ 2.0, 4.0 and 6.0 t ha^{-1} increased the nitrogen content in seed to the extent of 14.33, 25.08 and 35.83, respectively as compared to control.

Effect of sulphur: The effect of sulphur on nitrogen content in seed was found significant. The application of sulphur significantly increased the nitrogen content in seed as compared to control. However, the difference in nitrogen content under S_{40} and S_{60} treatments for seed was non-significant. The maximum value of nitrogen content (3.96%) was recorded under treatment S_{60}, while, minimum (3.09%) under S_0 in seed, respectively. Application of sulphur S_{20}, S_{40} and S_{60} increased the N content of seed to the extent of 16.50, 28.01 and 28.99 per cent, respectively as compared to control (S_0).

Interaction effect between vermicompost and sulphur on N content in seed of mustard: Table 3 showed that interaction effect between vermicompost x sulphur was found significant for N content in seed. Significant higher N content in seed was recorded with 40 kg S ha^{-1} in combination with 6.0 t ha^{-1} vermicompost, which was signicantly superior to rest of the treatment combi-

nations except S_{60} + $V_{6.0}$. The minimum N content in seed was found under control.

Phosphorus

Effect of vermicompost: The phosphorus content in seed increased significantly with increasing levels o fortified vermicompost. The maximum phosphorus content in seed (0.929 %) was found under the treatment $V_{6.0}$ and minimum (0.677 %) under control (V_0). The application of fortified vermicompost @ 2.0, 4.0 and 6.0 t ha^{-1} increased the phosphorus content of seed to the extent of 15.65, 27.03 and 37.22 per cent, respectively as compared to control.

Effect of sulphur: The effect of sulphur on phosphorus content in seed was recorded significant (Table7). The application of sulphur significantly increased to the phosphorus content in seed as compared to control. However, the difference in phosphorus content for the seed with treatments S_{40} and S_{60} was found non-significant. In seed maximum value of phosphorus content was recorded under S_{60} and minimum under S_0. Application of sulphur S_{20}, S_{40} and S_{60} increased the phosphorus content of seed to the extent of 17.39, 28.65 and 29.09 per cent, respectively as compared to control (S_0)

Interaction effect between vermicompost and sulphur on P content in seed of mustard: Combined effect of levels of vermicompost and sulphur on P content in seed was found to be significant (Table 4).

The significantly higher P content in seed was recorded under 40 kg S ha^{-1} in combination with 4.0 t ha^{-1} vermicompost, which was signicantly superior to rest of the treatment combinations except S_{40} + $V_{6.0}$ and S_{60} + $V_{4.0.}$ Minimum P content in seed was recorded when neither sulphur nor vermicompost was applied.

Sulphur

Effect of vermicompost: The critical examination of data presented in Table 7 showed that sulphur content in the seed increased significantly with increasing levels of fortified vermicompost. The maximum sulphur content in seed (1.133 %) was found under the treatment $V_{6.0}$ and the minimum (0.672 %) under control (V_0). The application of fortified vermicompost @ 2.0, 4.0 and 6.0 t ha^{-1} increased the sulphur content in seed to the extent of 29.61, 51.63 and 68.60 per cent, respectively as compared to control.

Effect of sulphur: The perusal of the data in Table 7 revealed that the effect of sulphur on sulphur content in seed was found significant. The application of sulphur significantly increased the sulphur content in seed as compared to control. However, the difference in sulphur content under treatments S_{40} and S_{60} for seed and was observed non-significant. The maximum value of sulphur (0.999 %) content was recorded under $S_{60,}$ while, the minimum (0.795 %) under S_0. Application of sulphur (S_{20}, S_{40} and S_{60}) treatments increased the sulphur content in seed to the extent of 14.46, 24.65 and 25.66 per cent, respectively as compared to control (S_0).

Interaction effect between vermicompost and sulphur on sulphur content in seed of mustard: Data mentioned in table 5 showed that Interaction effect between vermicompost x sulphur was found significant for S content in seed. Sulphur content in seed of mustard was found significantly higher with treatment combination of 40 kg S ha^{-1} and 6.0 t ha^{-1} vermicompost, which was signicantly superior to rest of the treatment combinations except S_{60} + $V_{6.0}$. The minimum S content in seed was found under S_0V_0 treatment combination.

Sulphur uptake

Effect of vermicompost: It is evident from the data presented in Table 7 showed that sulphur uptake by seed of mustard increased significantly with increasing levels of fortified vermicompost. The maximum sulphur uptake by seed (21.26 kg ha^{-1}) was obtained under $V_{6.0,}$ while, the minimum (7.05 kg ha^{-1}) under V_0. The application of fortified vermicompost @ 2.0, 4.0 and 6.0 t ha^{-1} increased the sulphur uptake by seed to the extent of 71.34, 144.39 and 201.56 per cent, respectively as compared to control.

Effect of sulphur: Data pertaining to sulphur uptake mentioned in Table 7 showed that the application of sulphur significantly increased sulphur uptake by seed of mustard. The maximum value of sulphur uptake was recorded under S_{60} followed by S_{40}, S_{20} and S_0 in seed. Application of sulphur (S_{20}, S_{40} and S_{60}) treatments increased the sulphur uptakeby seed to the extent of 28.90, 52.04 and 54.46 per cent, respectively as compared to control.

Interaction effect between vermicompost and sulphur on sulphur uptake by seed of mustard: Combined effect of levels of vermicompost and sulphur on sulphur uptake by seed was found to be significant (Table 6). The significantly higher S uptake by seed was recorded with treatment combination 40 kg S ha^{-1} and 6.0 t ha^{-1} vermicompost, which was signicantly superior to rest of the treatment combinations except S_{60} + $V_{6.0}$. The minimum S uptake by seed was recorded when neither sulphur nor vermicompost was applied.

DISCUSSION

The increase in grain yield with the application of vermicompost might be due to the effect of vermicompost in improving the physical condition of soil, and providing balanced supply of nutrients required for proper growth and development of the crop. The results corroborate with finding of Singh and Singh (2006) conducted a field experiment at Bhartpur (Rajasthan) and observed that application of FYM @ 5 t ha^{-1} had significant effect on primary and secondary branches per plant of mustard over control. Akbari *et al.* (2010) recorded that the application of enriched compost @ 6 t/ha was proved better for obtaining maximum uptake of N, P and K by soybean as well as groundnut and P and K uptake by sesame. Treatments involving enriched compost or vermicompost found beneficial in respect to availabil-

ity of various nutrients at harvest. The increase in grain yield with application of S might be because of the fact that S activates some proteolytic enzymes, helps in synthesis of vitamins and carbohydrates which are translocated to reproductive structures. Similar findings were also reported by Jogi *et al.* (2009) that growth attributes increased significantly with increasing levels of sulphur up to highest level of 40 kg S $ha^{-1}$and Kapur *et al.* (2010) reported that yield attributes like plant height, number of primary and secondary branches per plant, number of siliqua per plant, number of seeds per silique and test weight were recorded significantly higher with application of 60 kg S ha^{-1}.The increase in grain yield due to conjoint application of vermicompost and sulphur might be due to development of better nutritional environment of soil besides balance supply of nutrients throughout the entire growth period of the crop.

Significantly, improved N, P, K, and S contents in seed due positive influence of vermicompost application on nutrient content in mustard crop appears to be due to improved nutrient levels both in the root zone and plant system. Thus, positive impact of vermicompost application on both these aspects ultimately led to higher accumulation of nutrients. These results are in line with the findings of Akbari *et al*. (2010), Singh *et al*. (2007) and Singh *et al*. (2006). The increase in availability of these nutrients in the root zone coupled with increase in metabolic activity at cellular levels might have increased nutrient uptake and their accumulation in the vegetative plants parts. Improvement of metabolisms led to greater translocation of these nutrients to reproductive organs of the crop and ultimately increases their contents in seed. These results are in close conformity with those of Vasanthi and Kumarswamy (1999), and Rajkhowa *et al*. (2000). The nitrogen seed increased significantly with the increase in the level of sulphur. The N contents increased significantly upto application of 40 kg S ha^{-1}. As stated earlier that S is a most important constituent of amino acids, like: methionine, cysteine and cystine and also involved in synthesis of enzymes, auxins and other substances of physiological importance. These results are in agreement with the findings of Kumawat and Aswal (2005) who had reported that N in seed and stover of mustard was significantly influenced by application of S upto 75 kg ha^{-1}. The increase in N, P, K, and S contents of mustard have also been reported by Akbari *et al*. (2010), Singh and Meena (2004), Kumawat and Aswal (2005), Piri and Sharma (2006), Syed *et al*. (2006) and Sharma *et al*. (2009). Significant increase S uptake due to application of vermicompost @ 6.0 ha^{-1} was recorded under present investigation. Increased uptake of S seems to be due to the fact that uptake of nutrients is a product of biomass and its nutrient content. Sharma *et al*. (2009) reported that the application of integrated nutrient management recorded significantly higher total uptake of S over the control. The sulphur contents and uptake in seed increased significantly with the increase in the level of sulphur. The favourable conditions for microbial as well as chemical activities due to addition of vermicompost integrated with other nutrients augmented the mineralization of nutrients and ultimately increased the available nutrient status of the soil. These results are in agreement with those of Jat and Mehra (2007) reported effect of sulphur and zinc on yield, macronutrient content in and uptake by mustard on Haplustepts and Zizala *et al.* (2008) conducted experiment at Anand loamy sand (Typic Ustochrepts), Gujarat, India. Sharma and Arora (2008) were conducted for two consecutive years during the rabi season in sandy loam soils of Jammu (north India) under rainfed conditions to study the effect of S through gypsum or pyrite either in natural or ground from among the different treatments, S application at 50 kg S ha^{-1} of ground gypsum recorded the significantly highest uptake, which lead to an increase of 30 and 29.8 per cent in the first and second year respectively, over the control.

Conclusion

As regards interactive effects of treatment, synergistic behavior was noted between 6.0 t vermicompost ha^{-1} 40 kg S ha^{-1} for seed yield, nitrogen, and phosphorus contents and also sulphur content and uptake by seed of mustard. The concomitant effect of 6.0 t vermicompost ha^{-1} and 40 kg S ha^{-1} application was found highly pronounced on seed yield and sulphur content in seed of mustard.

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