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GROWTH AND QUALITY CHARACTERISTICS OF SESAME (*SESAMUM INDICUM* L.) AS INFLUENCED BY VERMICOMPOST AND CHEMICAL FERTILIZERS

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Abstract

An experiment was carried out in pot culture to assess the effect of integrated vermicompost and chemical fertilizers on soil physical and chemical attributes, sesame plant growth, seed yield, and nutrient concentrations in agricultural soil. Eleven treatments were arranged in a completely randomized design (CRD) with three replications together with the control. All the vegetative growth and yield promoting attributes *viz.* plant height (116.20 cm), leaf number (100 plant^{-1}), leaf area (29.34 cm^2), pod no. (100 plant^{-1}), and seed no. (64 pod^{-1}), and 1000 seeds weight (3.82g) was highest in T_{10} containing 15 t ha^{-1} vermicompost plus 70% RDF ($N_{21}P_{11}K_{14}S_5$ kg ha^{-1}). The control (T_1) displayed minimum yield performance and quality characteristics. The total N, P, K, S, Fe, and Zn concentrations and protein content in seeds were measured highest in T_{10}. This study revealed that combining vermicompost with inorganic fertilizer can improve sesame plant growth and seed nutrient content and is recommended for sesame production.

Keywords: Quality attributes, Growth and yield, Vermicompost, Inorganic fertilizers, Sesame.

Introduction

Sesame (*Sesamum indicum* L.), is a valuable oilseed crop with great demand for its oil and protein content particularly for developing nations like Bangladesh. It is a robust crop that may flourish under various abiotic stress conditions. It has remarkable antioxidants due to the presence of tocopherol and lignin. Sesame seeds contain a good amount of protein and amino acids, particularly methionine, a nutrient that rejuvenates the body against aging. These are abundant sources of vitamins (A, E, B_1, and B_2), fatty acids (palmitic, oleic, linoleic, and stearic acid), and minerals, including calcium and

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phosphorus. The crop's oil consists of 85% unsaturated fatty acid, is highly stable, reduces cholesterol, and prevents coronary heart diseases (Choudhary *et al.,* 2017). Sesame seeds are highly beneficial as seed contain 42-50% oil (25% protein, 16-18% carbohydrate and 42% essential linoleic acid) (Miah *et al.,* 2015). Due to its exceptional skin-care and cosmetic properties, sesame is the queen of oils. Nowadays, people are much more interested in buying sesame oil instead of mustard oil due to less cholesterol and the property of unsaturated fatty acid (lipid) in the daily diet. The finest quality medicinal and edible oil can be extracted from sesame. A wide range of animals can benefit from eating sesame oilcake, such as poultry, fish, cattle, goats, and sheep (Khan *et al.,* 2009). Due to the lack of non-shattering, water-logged, insect and disease-resistant varieties, low seed yields are currently limiting sesame expansion. Different improved varieties of oil seeds were released by the Bangladesh Agricultural Research Institute's Oilseed Research Centre, including Bari til-4, in 1976. As these varieties mature late, excess water can be detrimental to their growth.

Applying inorganic fertilizers, no doubt increases production but is becoming costlier day by day (Shaikh *et al.,* 2010). The suboptimal application of fertilizers and less soil fertility cause nutrient depletion and yield decline. Applying compost with or without inorganic fertilizers is considered a sustainable agricultural production system because it ameliorates soil fertility and increases crop productivity. It varies according to the cropping pattern and ecological, social, and economic situations (Duhoon *et al.,* 2004). The utilization of vermicompost is suitable for overcoming the unwanted factor of pollution hazards from excessive inorganic fertilizers (N, P, and K) use. Experimented with different fertilizer sources under an integrated nutrient management system reported positive effects for sesame production. Using vermicompost and mineral fertilizers has a beneficial effects on seed quality and sesame production. Thus, the investigation highlighted the benefits of using vermicompost and inorganic fertilizers as an environmentally sustainable agriculture alternative in sesame cultivation in Bangladesh.

Materials and Methods

Soil sampling was performed from a local vegetable field in Char Nilakshmia, Mymensingh district, Bangladesh (Fig. 1). The sampling area is medium-high land and the Brahmaputra river surrounds the village. This village is located at 24°43'46.5" N and 90°28'31.1" E. Temperature was 27ºC and relative humidity 68%. The soil texture is silt loam (4.65% sand, 68.34% silt, 27.01% clay).

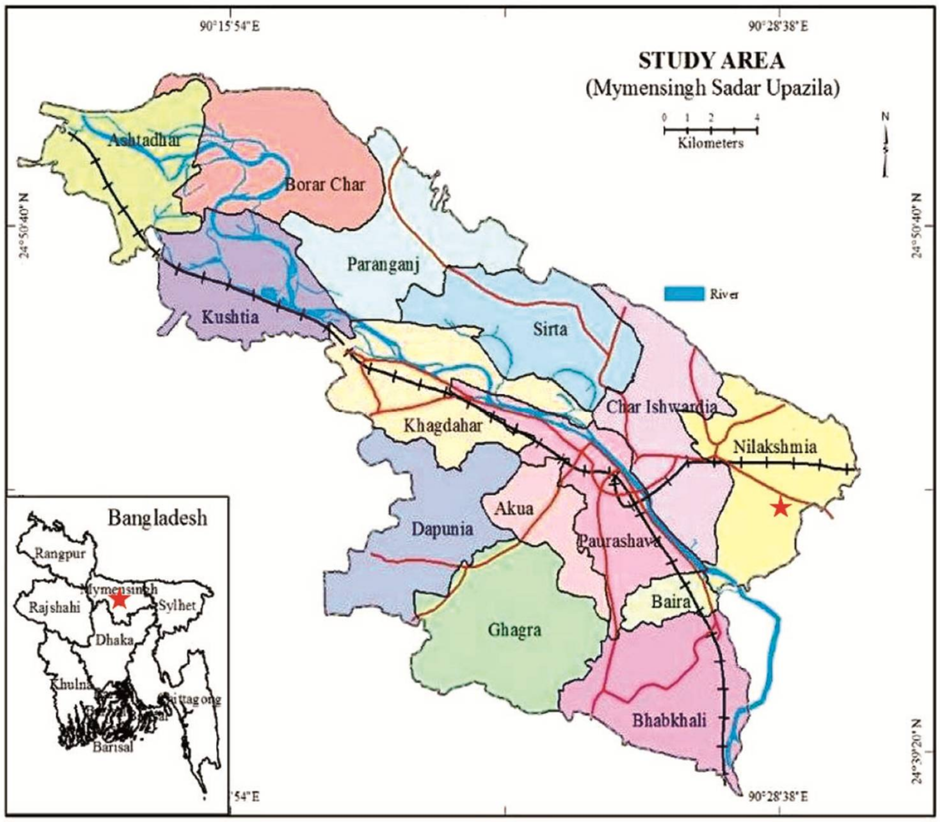

Fig. 1. Sampling site location (Mymensingh Sadar Upazila) (Source: Rakib *et al.,* 2017)

The experiment was laid out at the Soil, Water, and Environment Department's net house at the University of Dhaka, Bangladesh. A ten-kilogram plastic pot was filled with eight-kilogram soil dried in the air. Seeds were sown in treated soil, followed by irrigation. Vermicompost as organic and urea, TSP, MoP, and gypsum as inorganic fertilizer were applied. The pots under study were arranged following a completely randomized design (CRD). Three replications of each of the eleven treatments, including the control. After 90 days, the crops were harvested.

The treatments variables were T_1: Control (-VC & -RDF $N_{30}P_{15}K_{20}S_7$ kg ha^{-1}), T_2: 5 t ha^{-1} vermicompost, T_3: 10 t ha^{-1} vermicompost, T_4: 15 t ha^{-1} vermicompost, T_5: 5 t ha^{-1} vermicompost + 60% RDF ($N_{18}P_9K_{12}S_4$ kg ha^{-1}), T_6: 10 t ha^{-1} vermicompost + 60% RDF ($N_{18}P_9K_{12}S_4$ kg ha^{-1}), T_7: 15 t ha^{-1} vermicompost + 60% ($N_{18}P_9K_{12}S_4$ kg ha^{-1}), T_8: 5 t ha^{-1}

vermicompost + 70% RDF ($N_{21}P_{11}K_{14}S_5$ kg ha^{-1}), T_9: 10 t ha^{-1} vermicompost + 70% RDF ($N_{21}P_{11}K_{14}S_5$ kg ha^{-1}), T_{10}: 15 t ha^{-1} vermicompost + 70% RDF ($N_{21}P_{11}K_{14}S_5$ kg ha^{-1}) and T_{11}: 100% RDF ($N_{30}P_{15}K_{20}S_7$ kg ha^{-1}). After 90 days, the sesame plant harvest was completed. The whole plant was uprooted, and then the seeds were collected. To carry the seeds to the lab, polythene bags were used to collect the seeds. Soft tissue paper was used to wrap the seeds after they were washed with distilled water. The fresh and dry weights of the seeds were recorded. Plant and post-harvest soil samples were dried in exposure to sunlight on the rooftop for three days, and then plant samples were oven-dried for 48 hours at 65°C. A mechanical grinder machine and a wooden hammer grounded plant and post-harvest soil samples, respectively. Both samples were sieved using a 2mm sieve and stored in plastic pots.

The pre-planting and post-harvest soil and sesame seeds were analyzed chemically to determine their available and total nutrient concentrations. Soil available nitrogen was determined by extracting 10g of soil with 1N KCl and distilling by Kjeldahl's distillation apparatus using Devarda's alloy (Huq and Alam, 2005). Olsen extractant (0.5M $NaHCO_3$) at pH 8.5 was used to extract available phosphorous from soil (Olsen *et al.*, 1954). The exchangeable potassium in soil was extracted with 1N ammonium acetate at pH 7 and the extractant was analyzed by a JENWAY flame photometer (Pratt, 1965). Soil available sulfur was determined by turbidity created by suspended barium sulfate using a tween-80 stabilizer after extracting with Morgan extractant at pH 4.8 (Morgan, 1941). A HACH DR 5000 spectrophotometer measured the turbidity at 420 nm wavelength (Page *et al.*, 1989). According to Walkley and Black (1934), the soil organic carbon was determined following the 'wet oxidation method'. The organic carbon percentage was multiplied by 1.724 to calculate soil organic matter content (Piper, 1950). Soil pH was determined using a soil-water medium at 1:2.5 (Jackson, 1973) using HANNA Instruments HI 2211 pH/ORP meter and EC at a ratio of 1:5 (Richards, 1954) using EUTECH Instruments CON 700. According to Nagornyy (2013), seed (0.2g) and vermicompost (0.5g) were digested for total nitrogen content determination in a Kjeldahl digestion flask. Seed (0.2g) and vermicompost (0.5g) were digested with nitric-perchloric acid (HNO_3:$HClO_4$ = 2:1) to determine total phosphorous, potassium, sulfur, iron, and zinc as described by Huq and Alam (2005). Fe and Zn contents were obtained by Atomic Absorption Spectrometer (VARIAN AA240). IBM SPSS Statistics 26 was used for statistical analysis (ANOVA, LSD at 5% probability level), and MS Excel 2019 for tabular analysis of the obtained data.

Results and Discussion

Analysis of physico-chemical attributes of pre-planting and post-harvest soils: The application of vermicompost to the initially collected soil increased soil pH to 8.34 and EC to 264 mS/m in the post-harvest soil (Table 1). Macronutrients NPKS and micronutrients Fe and Zn concentrations were reduced in some and increased in others of the post-harvest soil. The plants uptake the nutrient, correspondingly reducing nutrient composition in the post-harvest soil.

Table 1. Physico-chemical attributes of pre-planting and post-harvest soils.

Attributes	Pre-planting soil	Post-harvest soil
pH	7.50	8.34
EC(mS/m)	240.00	264.00
Organic carbon (%)	0.75	0.67
Organic matter (%)	1.30	1.15
Available N (ppm)	63.00	25.20
Available P (ppm)	175.00	213.54
Available K (ppm)	29.00	19.21
Available S (ppm)	17.09	27.74
Available Fe (ppm)	169.21	168.54
Available Zn (ppm)	7.00	7.02

Effects on plant growth and yield attributes: A statistically significant variation ($p \leq 0.05$) at 90 DAS was observed in growth and yield performances of some vegetative parameters, i.e., plant height, number of leaves plant^{-1}, leaf area, and pod no. plant^{-1} under various vermicompost and inorganic fertilizers are presented in Table 2. Among the treatments, 15 t ha^{-1} vermicompost plus 70% RDF ($N_{21}P_{11}K_{14}S_5$ kg ha^{-1}) (T_{10}) produced the maximum plant height (116.2 cm), followed by 10 t ha^{-1} vermicompost plus 70% RDF ($N_{21}P_{11}K_{14}S_5$ kg ha^{-1}) (T_9), while the control (T_1) showed the shortest (108.10 cm) plant height. The increase in plant height due to applying the higher amount of vermicompost and NPKS fertilizers may be responsible for better vegetative growth. These findings conform with that of Malik *et al.* (1988), who reported that increasing NPK fertilizers application escalated plant height. Likewise, leaf number (100 plant^{-1}), leaf area (29.34 cm^2), and pod no. (100 plant^{-1}) was found to be highest in T_{10} compared to the sole 5 t ha^{-1} vermicompost (T_2) and RDF ($N_{30}P_{15}K_{20}S_7$ kg ha^{-1}) (T_{11}). The control

(T_1) showed the minimum values compared to other treatments. Syed *et al.*, (2022) reported that vermicompost and NPK fertilizers significantly improved spinach's vegetative growth parameters.

Table 2. Influence of soil-applied vermicompost (VC) and NPKS fertilizers on yield and growth contributing attributes of sesame plants at 90 days after sowing (DAS).

Treatments	Plant height (cm)	No. of leaves plant^{-1}	Leaf area (cm^2)	Pod no. plant^{-1}
T_1: Control (-VC & - RDF $N_{30}P_{15}K_{20}S_7$ kg ha^{-1})	108.10	78	20.75	82
T_2: VC 5 t ha^{-1}	110.80	80	20.95	86
T_3: VC 10 t ha^{-1}	111.20	84	21.40	89
T_4: VC 15 t ha^{-1}	113.40	86	22.50	90
T_5: VC 5 t ha^{-1} + 60% RDF $N_{18}P_9K_{12}S_4$ kg ha^{-1}	114.50	88	23.90	90
T_6: VC 10 t ha^{-1} + 60% RDF $N_{18}P_9K_{12}S_4$ kg ha^{-1}	115.20	90	24.50	93
T_7: VC 15 t ha^{-1} + 60% RDF $N_{18}P_9K_{12}S_4$ kg ha^{-1}	120.00	91	25.05	96
T_8: VC 5 t ha^{-1} + 70% RDF $N_{21}P_{11}K_{14}S_5$ kg ha^{-1}	112.30	93	26.09	97
T_9: VC 10 t ha^{-1} + 70% RDF $N_{21}P_{11}K_{14}S_5$ kg ha^{-1}	114.70	96	27.50	98
T_{10}: VC 15 t ha^{-1} + 70% RDF $N_{21}P_{11}K_{14}S_5$ kg ha^{-1}	116.20	100	29.34	100
T_{11}: RDF $N_{30}P_{15}K_{20}S_7$ kg ha^{-1}	114.20	91	22.98	93
LSD at 5%	**0.11**	**1.95**	**1.14**	**1.36**

Figure 2 illustrates that the highest number of seeds (64 pod^{-1}) and 1000 seed weight (3.82 g) were found in vermicompost 15 t ha^{-1} plus 70% RDF ($N_{21}P_{11}K_{14}S_5$ kg ha^{-1}) (T_{10}) due to the increased application of vermicompost, along with chemical fertilizers. The sole vermicompost 5 t ha^{-1} (T_2) and RDF ($N_{30}P_{15}K_{20}S_7$ kg ha^{-1}) (T_{11}) showed reducing trends in comparison with the remaining treatments, while the control T_1 showed the lowest values in all parameters. These results corroborate with Hafiz *et al.* (2012), who found that sesame seed weight increased significantly with increased phosphorus fertilizer application.

The integrated application of vermicompost and chemical fertilizers improved seed quality attributes. These results aligned with those of Mankar *et al.* (1995), who reported that with increasing application of nitrogen and phosphorous fertilizer rates, the weight of 1000 sesame seeds increased.

Effects on mineral nutrient composition: The application of vermicompost and inorganic fertilizer in combination has pronounced effects on sesame seed nutrient concentrations due to their crucial role in forming a robust and healthy root system that helps plants absorb sufficient nutrients from the soil. There were statistically significant differences ($p \leq 0.05$) among the different nutrient content statuses in sesame seeds as affected by the application of different treatments compared to the control (T_1) presented in Table 3.

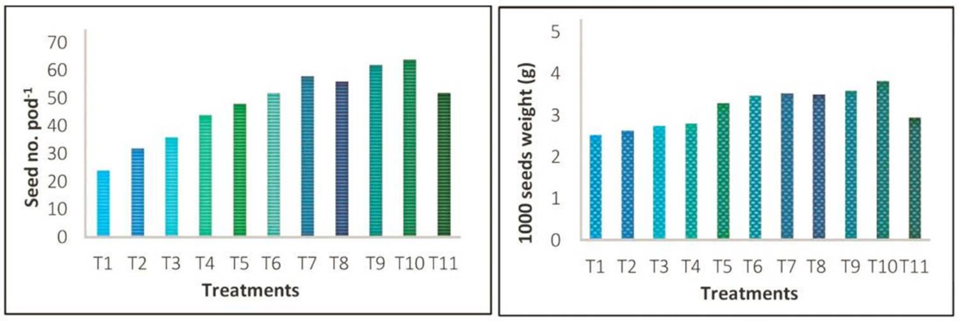

Fig 2. Effects of soil-applied vermicompost (VC) and NPKS fertilizers on seed no pod^{-1} and 1000 seeds weight (g) of sesame seeds at 90 days after sowing (DAS).

The higher accumulation of mineral nutrients and protein content in sesame seeds was recorded at 15 t ha^{-1} plus 70% RDF ($N_{21}P_{11}K_{14}S_5$ kg ha^{-1}) (T_{10}). The control (T_1) gave sesame seeds little value in nutrients and protein content. Other pots treated with only vermicompost or inorganic fertilizer had a lower nutrient composition than the other treatments. Based on early determinations, the computation N*6.25 (1/0.16 = 6.25) was used for nitrogen content conversion into protein content (Lourenco *et al.,* 1998). Application of all the treatments, either sole or combined, affected the availability of protein content in sesame seeds. Control pot (T_1) gave a significantly lower value (18.44%) for protein content compared to the pots treated with15 t ha^{-1} plus 70% RDF ($N_{21}P_{11}K_{14}S_5$ kg ha^{-1}) (T_{10}) and 10 t ha^{-1} plus 70% RDF ($N_{21}P_{11}K_{14}S_5$ kg ha^{-1}) (T_9), followed by the remaining treatments where varying but almost similar values were observed with T_8, T_7, and T_6. A simillar result was reported by Elleuch *et al.* (2007), that sesame seeds contained 18-25% protein content.

Effects on post-harvest soil: Soil samples after harvesting were analyzed to observe the changes that occurred under various treatments (Table 4). A significant variation ($p \leq 0.05$) was observed in the physico-chemical properties (pH, EC, organic carbon, organic matter), available macronutrients (N, P, K, and S), and micronutrient content (Fe, Zn,) which followed the proper laboratory methods for determination.

Table 3. Influence of soil-applied vermicompost (VC) and NPKS fertilizers on total macro- and micro-nutrient concentrations of sesame seeds at 90 days after sowing (DAS).

Treatments	N (%)	P (%)	K (%)	S (%)	Protein (%)	Fe (ppm)	Zn (ppm)
T_1: Control (-VC & - RDF $N_{30}P_{15}K_{20}S_7$ kg ha^{-1})	2.95	0.63	0.91	2.99	18.44	350.87	32.03
T_2: VC 5 t ha^{-1}	3.12	0.65	0.95	2.99	19.50	358.57	35.90
T_3: VC 10 t ha^{-1}	3.40	0.64	0.81	7.01	21.31	362.45	37.23
T_4: VC 15 t ha^{-1}	3.44	0.70	0.81	4.33	21.50	370.46	40.31
T_5: VC 5 t ha^{-1} + 60% RDF $N_{18}P_9K_{12}S_4$ kg ha^{-1}	3.65	0.58	0.84	4.54	22.81	355.90	36.87
T_6: VC 10 t ha^{-1} + 60% RDF $N_{18}P_9K_{12}S_4$ kg ha^{-1}	3.72	0.61	0.76	2.99	23.25	367.34	38.09
T_7: VC 15 t ha^{-1} + 60% RDF $N_{18}P_9K_{12}S_4$ kg ha^{-1}	3.80	0.67	0.89	3.98	23.75	379.32	40.98
T_8: VC 5 t ha^{-1} + 70% RDF $N_{21}P_{11}K_{14}S_5$ kg ha^{-1}	3.88	0.65	0.61	3.44	24.25	360.56	37.09
T_9: VC 10 t ha^{-1} + 70% RDF $N_{21}P_{11}K_{14}S_5$ kg ha^{-1}	3.90	0.57	0.69	5.22	24.37	387.55	42.91
T_{10}: VC 15 t ha^{-1} + 70% RDF $N_{21}P_{11}K_{14}S_5$ kg ha^{-1}	4.03	0.70	0.89	7.01	25.18	393.34	43.02
T_{11}: RDF $N_{30}P_{15}K_{20}S_7$ kg ha^{-1}	3.39	0.24	0.84	5.22	21.23	382.73	34.09
LSD at 5%	**0.07**	**0.01**	**0.02**	**0.98**	**0.15**	**2.62**	**1.43**

Table 4. Post-harvest soil's physico-chemical attributes analysis.

Treatments	pH	EC (mS/m)	OC (%)	OM (%)
T_1: Control (-VC & - RDF $N_{30}P_{15}K_{20}S_7$ kg ha^{-1})	7.50	235.00	0.72	1.25
T_2: VC 5 t ha^{-1}	8.30	105.20	1.06	1.82
T_3: VC 10 t ha^{-1}	7.98	193.50	0.23	0.38
T_4: VC 15 t ha^{-1}	8.28	97.30	0.56	1.00
T_5: VC 5 t ha^{-1} + 60% RDF $N_{18}P_9K_{12}S_4$ kg ha^{-1}	8.11	108.90	0.28	0.48
T_6: VC 10 t ha^{-1} + 60% RDF $N_{18}P_9K_{12}S_4$ kg ha^{-1}	7.86	204.00	0.31	0.53
T_7: VC 15 t ha^{-1} + 60% RDF $N_{18}P_9K_{12}S_4$ kg ha^{-1}	7.77	174.30	0.25	0.43
T_8: VC 5 t ha^{-1} + 70% RDF $N_{21}P_{11}K_{14}S_5$ kg ha^{-1}	8.34	134.70	0.58	1.00
T_9: VC 10 t ha^{-1} + 70% RDF $N_{21}P_{11}K_{14}S_5$ kg ha^{-1}	7.96	263.00	0.75	1.29
T_{10}: VC 15 t ha^{-1} + 70% RDF $N_{21}P_{11}K_{14}S_5$ kg ha^{-1}	7.59	264.00	0.67	1.15
T_{11}: RDF $N_{30}P_{15}K_{20}S_7$ kg ha^{-1}	8.18	115.30	0.73	1.25
LSD at 5%	**0.05**	**56.23**	**0.14**	**0.09**

The pH of the soil varied between 7.50 and 8.34, depending on the treatments. The maximum pH was recorded in treatment T_8 and the minimum in treatment T_1 (control). The highest EC recorded in treatment T_{10} was 264 (mS/m), and the lowest, 97.30 (mS/m), was recorded in treatment T_4. Mahmoud *et al.* (2009) observed the maximum EC value under higher doses of organic and inorganic fertilizers, which agrees with the present findings.

Effects on post-harvest soil's available macro and micronutrients: The available macro and micronutrient content of post-harvest soil under various treatments are shown in Table 5. A statistically significant variation ($p \leq 0.05$) was present among N, P, K, S, Fe, and Zn. The maximum amount of available nitrogen (118.50 ppm), sulfur (29.56 ppm), iron (181.87 ppm), and zinc (8.90 ppm) in soils were noticed in the treatment vermicompost 10 t ha^{-1} plus 60% RDF ($N_{18}P_9K_{12}S_4$ kg ha^{-1}) (T_6), except phosphorous (214.21 ppm) and potassium (29.25 ppm) showed highest concentration in the treatment vermicompost 10 t ha^{-1} plus 70% RDF $N_{21}P_{11}K_{14}S_5$ kg ha^{-1}.

Table 5. Influence of vermicompost (VC) and NPKS fertilizers on the post-harvest soils macro- and micro-nutrient concentrations.

Treatments	N (ppm)	P (ppm)	K (ppm)	S (ppm)	Fe (ppm)	Zn (ppm)
T_1: Control (-VC & - RDF $N_{30}P_{15}K_{20}S_7$ kg ha^{-1})	33.10	150.17	28.03	16.79	157.68	6.69
T_2: VC 5 t ha^{-1}	50.30	156.83	25.02	22.26	170.32	7.85
T_3: VC 10 t ha^{-1}	38.20	185.52	23.33	24.09	173.09	7.23
T_4: VC 15 t ha^{-1}	89.30	157.83	23.80	25.91	178.56	8.50
T_5: VC 5 t ha^{-1} + 60% RDF $N_{18}P_9K_{12}S_4$ kg ha^{-1}	101.10	168.17	22.96	22.26	175.09	5.34
T_6: VC 10 t ha^{-1} + 60% RDF $N_{18}P_9K_{12}S_4$ kg ha^{-1}	118.50	182.85	25.99	29.56	181.87	8.90
T_7: VC 15 t ha^{-1} + 60% RDF $N_{18}P_9K_{12}S_4$ kg ha^{-1}	50.30	148.82	24.05	18.61	179.04	6.98
T_8: VC 5 t ha^{-1} + 70% RDF $N_{21}P_{11}K_{14}S_5$ kg ha^{-1}	30.70	201.86	24.78	24.09	180.76	7.50
T_9: VC 10 t ha^{-1} + 70% RDF $N_{21}P_{11}K_{14}S_5$ kg ha^{-1}	50.20	214.21	29.25	21.09	178.32	9.67
T_{10}: VC 15 t ha^{-1} + 70% RDF $N_{21}P_{11}K_{14}S_5$ kg ha^{-1}	25.20	213.54	19.21	27.74	168.54	7.02
T_{11}: RDF $N_{30}P_{15}K_{20}S_7$ kg ha^{-1}	62.50	182.21	22.58	23.10	180.93	8.72
LSD at 5%	**1.92**	**1.77**	**0.88**	**0.97**	**2.89**	**1.29**

As sesame plants uptake the nutrients for their production, all nutrient concentration was lowest in vermicompost 15 t ha^{-1} plus 70% RDF ($N_{21}P_{11}K_{14}S_5$ kg ha^{-1}) (T_{10}) after the control, except phosphorous (148.82 ppm) and sulfur (18.61 ppm) in treatment vermicompost 15 t ha^{-1} plus 60% RDF ($N_{18}P_9K_{12}S_4$ kg ha^{-1}). The other treatments displayed intermediary effects. According to Mamun *et al.* (2018), post-harvest soils treated with greater organic nitrogen sources and less urea application had higher available S concentrations. Singh *et al.* (1999) discovered that combining organic manures with NPKS improves soil S status. Vermicompost application increased the available iron concentration compared to the control (Angelova *et al*., 2013). Shuman (1999) found that the presence of organic fertilizers increases the zinc retention capacity of the soil.

Conclusion

Although all variables tested were significantly improved by 15 t ha^{-1} vermicompost plus 70% RDF ($N_{21}P_{11}K_{14}S_5$ kg ha^{-1}) (T_{10}), some of its values were nearly identical to vermicompost application 10 t ha^{-1} plus 70% RDF ($N_{21}P_{11}K_{14}S_5$ kg ha^{-1}) (T_9). The study findings suggest that vermicompost combined with inorganic fertilizers can improve Bangladesh's seed quality attributes, growth, and sesame yield. The benefits of vermicompost include improved soil fertility and plant nutrition, leading to increased growth and yield and improved seed weight and protein content. Thus, in order to recommend a viable agro-economic production at the growers' level, additional research with different varieties may be necessary for different Agro-Ecological Zones (AEZ) of Bangladesh.

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