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UTILIZATION OF VERMICOMPOST AND NPK FERTILIZERS ON THE GROWTH, YIELD, NUTRIENT AND PROTEIN CONTENT OF MUNG BEAN (*Vigna radiata* L.)

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Abstract

A pot experiment was conducted in Soil, Water and Environment department, University of Dhaka, during the late rabi season for 60 days with mung bean plants. The study was cnducted to evaluate the interactive effects of vermicompost and NPK fertilizers on mung bean plants' growth, yield, nutrient and protein content. The trial was laid out in a completely randomized design (CRD) followed by three replications, having ten treatments, including control. The first four treatments contained vermicompost mixed with soil at the rate of 2, 4, 6, and 8 ton ha^{-1}. The other four treatments contained 50% of $N_{12}P_{22}K_{10}$ kg ha^{-1}, while a single treatment possesses $N_{25}P_{45}K_{20}$ kg ha^{-1}. The growth and yield contributing parameters, *viz.* plant height (30 cm), leaf number (18 plant^{-1}), leaf area (152 cm^2), branch number (4 plant^{-1}), weight of seed (4.45 g), yield of fresh (17.81 g) and dry (10.32 g) mung bean plant was found maximum with T_{10} (vermicompost 8 ton ha^{-1} + $N_{12}P_{22}K_{10}$ kg ha^{-1}). The mineral nutrient content N (4.69%), P (0.08%) and K (0.65%) attained the highest in the harvested seed in the same T_{10}. The protein content (29.32%) was also found highest in T_{10}. On the basis of the findings, it may be recommended to use VC 8 ton ha^{-1} plus $N_{12}P_{22}K_{10}$ kg ha^{-1} to cultivate the mung bean in the context of Bangladesh.

***Key words*:** Mung bean; Vermicompost; Pot experiments; Growth and yield; Nutrient content.

INTRODUCTION

Mung bean (*Vigna radiata* L.), also known as the green gram, moong, or munggo (Philippines), is a plant species in the legume family. Traditionally cultivated in East, Southeast, and South Asia, mung bean is used in savory and sweet dishes. It is an annual crop cultivated mostly in rotation with cereals. The mung bean is an erect plant that is highly branched and is about 60 to 76 cm tall (Oplinger *et al.* 1990), looks more like a garden bean than a soya bean plant. The roots of mung beans are deep-rooted, just like the roots of black-eyed peas. The leaves are trifoliate like other legumes. The pale yellow flowers are borne in clusters of 12-15 near the top of the plant. Self-pollination occurs, so insects and winds are not required. Flowers will eventually develop into small, thin cylindrical pods. The pods turn darker in color as they mature. The seeds are free from glycosides. The three seed color exhibits a wide range of variations at maturity from yellow, greenish-yellow, light-green, and shiny green to dark-green, dull green, black, brown, and green mottled with black.

Pulse is a major protein source for Asian people, who largely depend upon cereals and pulses for their daily requirements. South Asian countries are the world's largest producers and consumers of pulses, comprising mainly chickpeas, pigeon peas, and mung beans. Easily digestible mung bean, high in protein, iron, and fiber, constitutes a balanced diet in combination with cereals and is an essential short, duration, drought-tolerant pulse crop. It is a good substitute for meat in most Asian diets, and a significant component of various cropping systems (Rudy *et al*. 2006). Mung bean is a substitute for animal protein and forms a balanced diet when used with cereals (Delice *et al.* 2011). Its yield and quality can be improved by the balanced use of fertilizers and by properly managing the organic manures. Moreover, a lack of attention to fertilizer use has also hampered the lowering of mung bean yield (Mansoor 2007).

Nutritionally, mung bean is the best and most popular crop of all pulses in Bangladesh. It is reported (Sun *et al.* 2022) that mung bean provides a high amount of protein (24.5%), lysine (460 mg/g N) and tryptophan (60 mg/g N). It is digestible and tasty. Azadi *et al.* (2013) found that it also contained a remarkable quantity of ascorbic acid and riboflavin (0.21 mg/100g). Aside from providing protein for the diet, mung beans also benefit soil fertility through the fixation of atmospheric nitrogen by symbiotic root *rhizobia* (Anjum *et al.* 2006), which not only meets the crop's nitrogen requirements but also benefits subsequent crops as well (Ali 1992). The agro-ecological conditions in Bangladesh are favourable for growing this crop. According to the BARC (2013), the optimum temperature varies from 20°C to 35°C according to the season. Additionally, mung beans grow well with minimal nutrients and are drought-tolerant. It is produced in an area of 0.18 Mha, with a total production of 0.20 MMT in Bangladesh (Krishi Diary 2016). Despite the best efforts to improve the mung bean varieties, the productivity of this crop is low, *i.e.* only around 500 kg ha^{-1}. This may be due to the lack of genotypes suitable for various cropping environments (Dikshit *et al.* 2009). In these circumstances, it can maximize the yield and quality of mung bean with judicial organic and inorganic fertilizer management. It is essential to increase the production of mung bean as national demand increases day by day. Vermicompost an alternative organic material combined with inorganic fertilizer act as a promoter of the yield and quality of mung bean.

In vermitechnology, surface and subsurface earthworm varieties are used (Ansari and Ismail 2012). Waste materials can be broken down into vermicompost by earthworms. Kale and Bano (1986) stated that vermiculture can considerably reduce the use of other fertilizers besides improving soil fertility. Vermicompost, finely divided peat-like with high water holding capacity, perfect structure, porosity, and aeration, is an organic fertilizer rich in nutrients, poor in readily biodegradable carbon and relatively free of any plant and human pathogens (Dominguez 2004). As a result, it is more environmentally friendly, more nutritious, and releases nutrients slowly that are readily absorbed by plants. It also eliminates the need for pesticides since plants are healthy and free from pests and diseases. Vermicompost is higher in nutrients than any other compost (N-1.5-2.5%, P-0.6-0.8% and K-1.2-1.5%) (Niranjan *et al.* 2010). Considering the above facts this study aimed to determine the combined use of vermicompost and NPK fertilizers on the growth, yield, nutrients, and protein content of mung beans.

MATERIAL AND METHODS

Collection of soil samples, fertilizers and seeds

The soil sample was collected within 0-15 cm depth from the surface by the composite soil sampling procedure. Approximately equal amounts of soil from a particular depth were taken from each sampling site and mixed thoroughly. All the samples were put in a polythene bag. Two paper tags with the required information, such as date, sampling depth, and name, were put inside and outside the bag. Then the bag was sealed with a rope and transported to the laboratory.

The soil sample was air-dried for seven days by spreading homogeneously on a clean piece of paper. Visible roots and debris were discarded from the soil sample. After air drying, larger and more massive aggregates were broken by gently crushing them with the help of a wooden hammer. The soil sample was allowed to pass through a 0.5 mm sieve and properly preserved in labeled plastic bottles for further analysis of physico-chemical properties (Table 1).

The percentage of sand, silt and clay were estimated by the process described by Bouyoucos (1962). The textural class of the soil sample was done by the USDA soil texture triangle, using the proportion of percentages. The moisture percentage and field capacities were 12.32% and 38.33%, respectively. All the fertilizers *viz.* urea, TSP, and MoP were collected from Bangladesh Agricultural Development Corporation (BADC) sales center, Dhaka. The sample of vermicompost (VC) was collected from the crop field of the Soil Resource Development Institute (SRDI).

The certified seeds of the pulse crop *Vigna radiata* L. selected for the study were purchased from a certified seed dealer of the Ministry of Agriculture, Bangladesh. The selected seeds were washed with de ionized water and surface sterilized with 0.1% mercuric chloride solution to keep off fungi spores and were sown in pots.

Table 1. Analysis of some physico-chemical properties of soil and vermicompost (VC).

Soil properties	Values	Soil properties	Values (%)	VC properties	Values	VC properties	Values(ppm)
% Sand	4.66	Available P (ppm)	420	pH	6.54	Cu	0.01
% Silt	68.33	Available K (ppm)	300	OC (%)	9.85	Zn	2.30
% Clay	27.01	Available S (ppm)	480	C:N ratio	8.75:1	B	0.605
Textural class	Silt loam	Total N	0.30	Total N (%)	1.30		
% Moisture	12.32%	Total P	0.07	Total P (ppm)	596.85		
% Field capacity	38.33%	Total K	0.36	Total K (ppm)	2425.45		
pH	7.54	Total S	0.11	Ca (ppm)	325.45		
EC (dS/m)	49.90	Fe	2.31	Mg (ppm)	140.33		
OC (%)	0.15	Mn	0.0421	Total Salts	3059		
OM (%)	0.26	Zn	0.0075	Mn	0.70		
Available N (ppm)	160	Cu	0.0026	Fe	0.12		

Pot experiment

A pot experiment was conducted in the net house on the premises of Soil, Water and Environment department, University of Dhaka, during the late rabi season (Mid-December of 2020). The breeding material of mung bean was collected. Eight kilograms of air-dried soil were taken in a 10 kg capacity plastic pot. The experiment laid out in a completely randomized design (CRD) consisted of ten treatments including control with three replications. A total of 10 (10*3=30) treatment combinations was distributed randomly in each pot. The treatments details were as follows: T_1: Control (-VC, -NPK), T_2: VC @ 2 t ha^{-1}, T_3: VC @ 4 t ha^{-1}, T_4: VC @ 6 t ha^{-1}, T_5: VC @ 8 t ha^{-1}, T_6: $N_{25}P_{45}K_{20}$ kg ha^{-1} RDF (Recommended dose of inorganic fertilizer), T_7: VC @ 2 t ha^{-1}+50% RDF ($N_{12}P_{22}K_{10}$ kg ha^{-1}), T_8: VC @ 4 t ha^{-1}+50% RDF ($N_{12}P_{22}K_{10}$ kg ha^{-1}), T_9: VC @ 6 t ha^{-1}+50% RDF ($N_{12}P_{22}K_{10}$ kg ha^{-1}), T_{10}: VC @ 8 t ha^{-1}+50% RDF ($N_{12}P_{22}K_{10}$ kg ha^{-1}).

Seven seeds of mung bean were sown in each pot. The pots were kept under a shady place in the net house covered by plastic bags and allowed to germinate. The germination of the seeds started 5 to 7 days after sowing. At the age of 15-20 day old, two healthy plants were kept in each pot, and the rest were uprooted. The different data of the number of leaves, height, and leaf area per plant were recorded at 10 day intervals up to 60 days. The moisture content of the soil was maintained between 50-75% of the field capacity throughout the growing period by frequent weighing and irrigation. Water was provided to all pots on a regular basis.

Harvesting

Mung bean was harvested at 60 days from the date of germination of seeds. All the plants were uprooted and the roots were washed with distilled water to remove any adhering particles on the root surface. The collected plants were separated into different parts like roots, stems, leaves and fruits. The fresh weights of the samples were taken immediately after harvesting. After that, the samples were oven-dried at 65°C for 48 hours that were previously packed in envelopes, and then oven-dry weight was taken. The dried samples were then ground separately by a mechanical grinder and preserved in plastic bottles for further chemical analysis.

Fig. 1. Mung bean plants with mature fruits before harvest.

Chemical analysis

To assess the nutritional status of soil and harvested mung bean plants, they were further chemically analyzed for their available and total nutrient content in the laboratories of the department of Soil, Water and Environment, University of Dhaka. The soil pH was determined by the glass electrode method (the ratio of the soil and water was 1: 2.5). Single extraction for available and digestion for total elemental analysis of the soil and plant samples were done. To determine available soil nitrogen (NH_4+NO_3), 10g of air-dried soil were taken for distillation. Available soil phosphorous was extracted by using the Bary and Kurtz method. The extract was estimated by the colorimetric method following the blue color method using ascorbic acid (Huq and Alam 2005). A spectrophotometer analyzed the extract at 880 nm. A flame photometer determined exchangeable potassium in soil with 766 or 769 nm filters after extracting the soil with 1N ammonium acetate at pH 7.0. The available soil sulfur was determined by the turbidity of suspended barium sulphate using Tween-80 solution as a stabilizer, and a spectrophotometer measured the turbidity at 420nm (Bardsley and Lancaster 1965).

The soil and plant samples were extracted with HNO_3 and $HClO_4$ acid digestion for total elemental analysis. The total nitrogen was determined by the Kjeldahl method (Jackson 1958). The total P content was determined by the vanadomolybodphosphoric yellow color method at 430nm and the total S content was determined by the turbidimetric method at 420nm using a spectrophotometer (model UV 1800); the total K content was determined by a JENWAY flame photometer (model PFP 7). The total iron (Fe), zinc (Zn), and manganese (Mn) content of the soil and plant samples were determined by the Varian Atomic Absorption Spectrophotometer (model AA240).

Statistical analysis

The data collected from the soil, plant growth and yield laboratory analysis were subjected to Analysis of Variance (ANOVA) using Microsoft Excel. The means were separated using the Fisher's Least Significant Difference (LSD) at 5% probability level.

RESULTS AND DISCUSSION

Plant height

It was measured from the plant's base to the leaf's tip. Plant height is an important morphological character. The mung bean plants' height varied significantly ($p \leq 0.05$) for different treatments, shown in Table 2. The highest plant height (30.00 cm) was obtained at T_{10} (VC @ 8 ton ha^{-1}+50% RDF-$N_{12}P_{22}K_{10}$ kg ha^{-1}) followed by T_8 (VC @ 2 ton ha^{-1}+50% RDF-$N_{12}P_{22}K_{10}$ kg ha^{-1}) and the lowest (25.50cm) in controlled treatment T_1 (-VC and -NPK). The highest plant height is due to the integrated use of fertilizer, and the lowest height produces as there was no fertilizer use. The height of the plant was significantly increased over control (T_1) in comparison to treated pots.

Ashraf *et al.* (2003) expressed that the plant height of mung beans varied in response to various doses of added fertilizer. Hossain *et al.* (2022) reported that the overall best growth, yield, and nutrient accumulation in the height of chili were achieved in 4 ton ha^{-1} Trichocompost+$N_{23}P_{10}K_{25}$ kg ha^{-1} treatment.

Table 2. Effects of vermicompost (VC) and NPK fertilizers on the height (cm) of mung bean plants grown in soil at 10 days' continuous intervals.

Treatments	**10^d**	**20^d**	**30^d**	**40^d**	**50^d**	**60^d**
T_1: Control (-VC & -NPK)	12.50	14.50	20.50	22.30	25.20	25.50
T_2: VC @ 2 t ha^{-1}	13.00	15.00	19.50	23.00	25.00	27.00
T_3: VC @ 4 t ha^{-1}	12.00	14.00	17.00	19.50	22.50	27.50
T_4: VC @ 6 t ha^{-1}	12.20	14.50	20.50	25.50	27.50	29.25
T_5: VC @ 8 t ha^{-1}	10.00	11.25	12.75	18.50	22.50	26.50
T_6: $N_{25}P_{45}K_{20}$ kg ha^{-1} RDF (Recommended dose of inorg. fertilizer)	12.00	14.50	17.25	21.00	24.50	26.75
T_7: VC @ 2 t ha^{-1} + 50% RDF ($N_{12}P_{22}K_{10}$ kg ha^{-1})	11.00	13.00	15.50	17.50	21.50	26.75
T_8: VC @ 4 t ha^{-1} + 50% RDF ($N_{12}P_{22}K_{10}$ kg ha^{-1})	13.25	15.20	17.00	21.00	27.85	29.50
T_9: VC @ 6 t ha^{-1} + 50% RDF ($N_{12}P_{22}K_{10}$ kg ha^{-1})	15.00	17.00	19.00	22.00	26.00	29.00
T_{10}: VC @ 8 t ha^{-1} + 50% RDF ($N_{12}P_{22}K_{10}$ kgha^{-1})	14.00	16.50	19.85	21.25	25.25	30.00
LSD at 5%	**2.85**	**3.36**	**4.69**	**4.95**	**5.61**	**4.39**

Number of leaves

The number of leaves per plant was recorded at 10, 20, 30, 40, 50 and 60 days after the seedlings transplant. The mean values of the number of leaves per plant are shown in Table 3. The highest number of leaves was obtained with T_{10} (VC @ 8 ton ha^{-1}+50% RDF-$N_{12}P_{22}K_{10}$ kg ha^{-1}).

Table 3. Effects of vermicompost and NPK fertilizers on the number of leaves (cm) of mung bean plants grown in soil at 10 days' continuous intervals.

Treatments	10^d	20^d	30^d	40^d	50^d	60^d
T_1: Control (-VC & -NPK)	2	5	7	11	13	15
T_2: VC @ 2 t ha^{-1}	3	6	7	11	14	17
T_3: VC @ 4 t ha^{-1}	3	5	9	12	14	16
T_4: VC @ 6 t ha^{-1}	3	6	8	11	11	14
T_5: VC @ 8 t ha^{-1}	2	4	8	11	14	17
T_6: $N_{25}P_{45}K_{20}$ kg ha^{-1} RDF (Recommended dose of inorg. fertilizer)	3	5	7	10	12	13
T_7: VC @ 2 t ha^{-1} + 50% RDF ($N_{12}P_{22}K_{10}$ kg ha^{-1})	2	4	9	10	13	15
T_8: VC @ 4 t ha^{-1} + 50% RDF ($N_{12}P_{22}K_{10}$ kg ha^{-1})	4	5	8	9	12	14
T_9: VC @ 6 t ha^{-1} + 50% RDF ($N_{12}P_{22}K_{10}$ kg ha^{-1})	2	5	8	10	13	16
T_{10}: VC @ 8 t ha^{-1} + 50% RDF ($N_{12}P_{22}K_{10}$ $kgha^{-1}$)	3	6	9	11	13	18
LSD at 5%	**NS**	**NS**	**NS**	**0.70**	**1.23**	**0.50**

The number of leaves was minimum at the control T_1 (-VC and -NPK) in all recording periods. The addition of inorganic fertilizer sole in T_6 could not significantly increase the number of leaves per plant. Application of VC @ 8 ton ha^{-1} in T_5 alone increased the number of leaves 17 $plant^{-1}$ at the respective periods. Higher leaf production was found with T_5 over T_6. Patil (1998) showed a similar result that the combination of vermicompost and inorganic fertilizers significantly increased the number of leaves $plant^{-1}$. Syed *et al.* (2023) found that vermicompost significantly improved spinach growth parameters and reduced heavy metal concentration in its leaves.

Leaf area

The results of the leaf area measurement are presented in Table 4. The values were measured at 10, 20, 30, 40, 50, and 60 days after the transplantation of seedlings. The highest leaf area on 60^{th} day was 152 cm^2 obtained in treatment T_{10} (VC @ 8 ton ha^{-1}+50% RDF-$N_{12}P_{22}K_{10}$ kg ha^{-1}). The leaf area was minimum at the control T_1 (-VC and -NPK) in all recording periods. Results showed all the intervals of days denoted increased leaf area of mung bean over control. Arancon *et al.* (2004) reported positive effects of vermicompost on the growth and yield of strawberries especially increasing the leaf area.

Table 4. Effects of vermicompost (VC) and NPK fertilizers on the leaf area (cm^2) of mung bean plants grown in soil at 10 days' continuous intervals.

Treatments	10^d	20^d	30^d	40^d	50^d	60^d
T_1: Control (-VC & -NPK)	13.00	26.15	29.24	32.50	44.75	95.00
T_2: VC @ 2 t ha^{-1}	15.25	27.20	41.25	58.90	74.85	146.00
T_3: VC @ 4 t ha^{-1}	16.74	27.75	30.25	52.75	76.75	151.00
T_4: VC @ 6 t ha^{-1}	17.60	35.95	48.25	54.58	70.50	135.00
T_5: VC @ 8 t ha^{-1}	20.18	36.75	49.90	61.35	82.75	144.00
T_6: $N_{25}P_{45}K_{20}$ kg ha^{-1} RDF (Recommended dose of inorg. fertilizer)	15.18	38.85	45.88	52.50	72.35	145.75
T_7: VC @ 2 t ha^{-1} + 50% RDF ($N_{12}P_{22}K_{10}$ kg ha^{-1})	19.90	28.76	42.85	64.50	80.65	150.00
T_8: VC @ 4 t ha^{-1} + 50% RDF ($N_{12}P_{22}K_{10}$ kg ha^{-1})	21.20	24.35	42.52	54.78	72.85	147.50
T_9: VC @ 6 t ha^{-1} + 50% RDF ($N_{12}P_{22}K_{10}$ kg ha^{-1})	15.75	38.12	54.25	66.42	82.75	148.75
T_{10}: VC @ 8 t ha^{-1} + 50% RDF ($N_{12}P_{22}K_{10}$ $kgha^{-1}$)	22.25	40.25	56.75	82.92	92.00	152.00
LSD at 5%	**NS**	**NS**	**4.08**	**2.25**	**5.32**	**7.45**

Fresh and dry weight of plants

The highest and lowest total fresh weight, 17.81 g and 8.32 g, were observed in T_{10} (VC @ 8 ton ha^{-1} + 50% RDF-$N_{12}P_{22}K_{10}$ kg ha^{-1}) and control T_1 (-VC and -NPK), respectively, presented in Table 5. Again, the highest (10.32 g) and lowest (3.74 g) dry weights were also observed in the treatment T_{10} and T_1, respectively. The second highest (33.07 g) and lowest (24.9 g) fresh weights were observed in T_8 (VC @ 4 ton ha^{-1}+50% RDF-$N_{12}P_{22}K_{10}$ kg ha^{-1}) and T_2 (VC @ 2 ton ha^{-1}), respectively, where the treatment T_7 (VC @ 2 ton ha^{-1}+50% RDF-$N_{12}P_{22}K_{10}$ kg ha^{-1}) showed almost the same result as treatment T_6 where a recommended dose of 100% NPK fertilizers ($N_{25}P_{45}K_{20}$ kg ha^{-1}) was applied. From the mean values of yields, inorganic fertilizer with vermicompost was detected best for the green weight of the plant. On the other hand, the combination without vermicompost and excess level of NPK fertilizer as 100% $N_{25}P_{45}K_{20}$ kg ha^{-1} were detected as poor for the green weight of the plant.

Number of branches, seeds and seeds weight

A significant variation ($p \leq 0.05$) in branches no. per plant and seeds weight of mung bean was observed among the treatments presented in Table 6. The highest number of branches 4 plant^{-1} and seeds per pod (3.50) was found in controlled treatment T_1 (-VC and -NPK). The highest amount of seed weight was found in treatment T_{10} (4.45 g) and the lowest was in treatment T_1 (0.89), respectively.

Table 5. Effects of vermicompost (VC) and NPK fertilizers on the fresh and dry weight of mung bean plants grown in soil at 10 days' continuous intervals.

Treatments	Fresh weight (g/plant)					Dry weight (g/plant)				
	Root	Shoot	Leaf	Seed	Total	Root	Shoot	Leaf	Seed	Total
T_1: Control (-VC & -NPK)	1.78	3.63	2.02	0.89	8.32	1.45	1.07	0.42	0.8	3.74
T_2: VC @ 2 t ha^{-1}	2.31	3.41	2.36	2.11	10.19	0.77	1.33	1.11	1.11	4.32
T_3: VC @ 4 t ha^{-1}	2.37	3.06	3.37	2.55	11.35	1.13	1.42	0.91	1.15	4.61
T_4: VC @ 6 t ha^{-1}	2.03	4.02	2.46	3.71	12.22	1.01	1.97	1.93	2.25	7.16
T_5: VC @ 8 t ha^{-1}	2.32	3.87	3.21	2.28	11.68	0.97	1.71	1.03	1.08	4.79
T_6: $N_{25}P_{45}K_{20}$ kg ha^{-1} RDF (Recommended dose of inorganic fertilizer)	1.97	3.11	3.21	2.32	10.61	1.36	1.68	1.13	1.25	5.42
T_7: VC @ 2 t ha^{-1} + 50% RDF ($N_{12}P_{22}K_{10}$ kg ha^{-1})	2.56	2.97	4.61	2.56	12.7	1.38	1.47	1.68	1.36	5.89
T_8: VC @ 4 t ha^{-1} + 50% RDF ($N_{12}P_{22}K_{10}$ kg ha^{-1})	2.41	5.35	5.05	4.12	16.93	1.04	2.22	2.54	3.03	8.83
T_9: VC @ 6 t ha^{-1} + 50% RDF ($N_{12}P_{22}K_{10}$ kg ha^{-1})	2.93	4.83	4.71	3.32	15.79	1.97	2.44	2.45	2.35	9.21
T_{10}: VC @ 8 t ha^{-1} + 50% RDF ($N_{12}P_{22}K_{10}$ kgha^{-1})	3.01	5.39	4.96	4.45	17.81	2.11	2.25	2.61	3.35	10.32
LSD at 5%	**0.52**	**0.24**	**1.23**	**0.80**	**1.20**	**0.07**	**0.83**	**0.07**	**0.50**	**0.20**

Total nitrogen content

Nitrogen is an essential macronutrient acting as a catalyst to support photosynthesis and facilitate plant growth. Nitrogen content varied with different treatment variations. Mean values of the nitrogen content (%) in the seed of mung bean presented in Table 7 as affected by different types of treatment. The mung bean plant's mineral nitrogen varied significantly ($p \leq 0.05$) for different combinations of NPK fertilizers and vermicompost.

Table 6. Effects of vermicompost (VC) and NPK fertilizers on the branch number and seed weights of mung bean plants grown in soil.

Treatments	**Branches no./Plant**	**Seeds/Pod**	**Weight of Seeds**
T_1: Control (-VC and -NPK)	2.00	3.50	0.89
T_2: VC @ 2 t ha^{-1}	3.00	3.60	2.11
T_3: VC @ 4 t ha^{-1}	3.00	3.66	2.55
T_4: VC @ 6 t ha^{-1}	3.00	4.18	3.71
T_5: VC @ 8 t ha^{-1}	3.00	3.65	2.28
T_6: $N_{25}P_{45}K_{20}$ kg ha^{-1} RDF (Recommended dose of inorganic fertilizer)	3.50	3.94	2.32
T_7: VC @ 2 t ha^{-1} + 50% RDF ($N_{12}P_{22}K_{10}$ kg ha^{-1})	3.50	3.86	2.56
T_8: VC @ 4 t ha^{-1} + 50% RDF ($N_{12}P_{22}K_{10}$ kg ha^{-1})	4.00	3.55	4.12
T_9: VC @ 6 t ha^{-1} + 50% RDF ($N_{12}P_{22}K_{10}$ kg ha^{-1})	3.50	3.81	3.32
T_{10}: VC @ 8 t ha^{-1} + 50% RDF ($N_{12}P_{22}K_{10}$ kgha^{-1})	4.00	4.69	4.45
LSD at 5%	**0.213**	-	**0.682**

Total phosphorus content

Phosphorus is a vital component of ATP, the energy unit of plants. ATP forms during photosynthesis have phosphorus in structure and processes from the beginning of seedling growth to grain formation and maturity. The total phosphorus content in the seed of the mung bean plant is presented in Table 7. It was found that there was no significance in different treatments containing phosphorous concentration and the value of phosphorous in the seed was obtained 0.08% in all including T_{10} (VC @ 8 ton ha^{-1}+50% RDF-$N_{12}P_{22}K_{10}$ kg ha^{-1}). Arsalan *et al.* (2016) reported similar results that the highest P content in seed (0.433%), in shoot (0.207%) and total uptake (12.00 kg ha^{-1}) was recorded from the combination dose of synthetic fertilizer and vermicompost @ 2 t ha^{-1} in other variety of mung bean.

Table 7. Effects of vermicompost and NPK fertilizers on the macronutrients (%) nitrogen (N), phosphorous (P), potassium (K) and micronutrients (ppm) iron (Fe), manganese (Mn), zinc (Zn) concentrations and protein content (%) in the seed of mung bean plant grown in soil.

Treatments	**N**	**P**	**K**	**Fe**	**Mn**	**Zn**	**Protein**
T_1: Control (-VC & -NPK)	3.50	0.08	0.50	5.23	0.73	1.73	21.88
T_2: VC @ 2 t ha^{-1}	3.53	0.08	0.60	5.31	0.88	1.85	22.54
T_3: VC @ 4 t ha^{-1}	3.66	0.08	0.62	5.76	0.97	1.95	22.88
T_4: VC @ 6 t ha^{-1}	3.82	0.08	0.55	6.17	0.89	2.11	26.16
T_5: VC @ 8 t ha^{-1}	3.61	0.08	0.54	6.74	0.92	2.35	22.82
T_6: $N_{25}P_{45}K_{20}$ kg ha^{-1} RDF (Recommended dose of inorg. fertilizer)	3.65	0.08	0.50	6.34	0.98	2.41	24.63
T_7: VC @ 2 t ha^{-1} + 50% RDF ($N_{12}P_{22}K_{10}$ kg ha^{-1})	3.94	0.08	0.53	6.45	0.91	2.25	24.15
T_8: VC @ 4 t ha^{-1} + 50% RDF ($N_{12}P_{22}K_{10}$ kg ha^{-1})	3.87	0.08	0.59	6.65	1.04	2.37	22.20
T_9: VC @ 6 t ha^{-1} + 50% RDF ($N_{12}P_{22}K_{10}$ kg ha^{-1})	4.19	0.08	0.51	6.75	1.03	2.68	23.84
T_{10}: VC @ 8 t ha^{-1} + 50% RDF ($N_{12}P_{22}K_{10}$ kgha^{-1})	4.69	0.08	0.65	6.98	1.06	2.56	29.32
LSD at 5%	**0.71**	**NS**	**0.05**	**NS**	**NS**	**NS**	**0.172**

Total potassium content

Potassium is one of the 17 essential elements required by plants for healthy growth and reproduction. Along with nitrogen and phosphorus, potassium is classified as a macronutrient. It is considered second only to nitrogen in terms of its importance to plant growth K content varies with different treatment variations. The variation was significant ($p \leq 0.05$) among different treatments containing potassium. The highest potassium content of 0.65% in the seed was recorded in treatment T_{10} (VC @ 8 ton ha^{-1}+50%

RDF-$N_{12}P_{22}K_{10}$ kg ha^{-1}) shown in Table 7. The lowest value was 0.50% in treatment T_1 (control). The potassium content in treatments T_2, T_3, and T_6 was significantly higher than in treatment T_1 (control).

Protein content

The protein content of foods is determined chiefly based on total nitrogen content. The Kjeldahl method is almost universally applied to determine nitrogen content; total nitrogen is multiplied by a factor to arrive at the protein content. This approach is based on the assumption that nearly all of the nitrogen in the diet is present as amino acids in proteins. On the basis of determination, the average nitrogen (N) content of the protein was found to be about 16 percent, which led to using of the calculation N*6.25 (100/16=6.25) to convert nitrogen content into protein content (Lourenco *et al*. 1998). The protein content of the mung bean ranged from 21.88% to 29.32% (Table 7) in the treatment of the study. Among different treatments, the protein content showed significant variation ($p \leq 0.05$). The highest protein content of seed was found in treatment T_{10} (VC @ 8 ton ha^{-1}+50% RDF-$N_{12}P_{22}K_{10}$ kg ha^{-1}), while the lowest was in control T_1.

Micronutrients content in plants

Various micronutrients, such as Fe, Zn, and Mn contents of the seeds of *Vigna radiata* L. for different treatments are given in Table 7. The ANOVA was performed to determine the significant difference among treatments for micronutrients of the seed of mung bean and it was found that there was no significant difference among micronutrients.

Physico-chemical parameters of post-harvest soil

Soil physico-chemical parameters were varied due to the effects of treatments at various levels. Changes in pH, EC (dS/m), organic carbon and organic matter of the post-harvest soils with the application of ten different treatments showed in Table 8. The initial organic matter of the control soil was 0.29%. The post-harvest pH (7.45-8.75), EC (54.0-91.5 dS/m), organic carbon (0.21-0.82%), organic matter content (0.36% - 1.45%), among the treatments varied significantly ($p \leq 0.05$).

Table 8. Analysis of physico-chemical parameters of post-harvest soil.

Treatments	pH	EC (dS/m)	OC (%)	OM (%)
T_1: Control (-VC & -NPK)	7.45	54.0	0.37	0.36
T_2: VC @ 2 t ha^{-1}	8.21	81.2	0.82	1.04
T_3: VC @ 4 t ha^{-1}	8.19	86.3	0.63	0.65
T_4: VC @ 6 t ha^{-1}	8.45	73.3	0.38	1.036
T_5: VC @ 8 t ha^{-1}	8.56	59.8	0.32	0.54
T_6: $N_{25}P_{45}K_{20}$ kg ha^{-1} RDF (Recommended dose of inorg. fertilizer)	8.26	61.3	0.21	0.65
T_7: VC @ 2 t ha^{-1} + 50% RDF ($N_{12}P_{22}K_{10}$ kg ha^{-1})	8.28	72.9	0.47	0.83
T_8: VC @ 4 t ha^{-1} + 50% RDF ($N_{12}P_{22}K_{10}$ kg ha^{-1})	8.73	78.6	0.59	0.85
T_9: VC @ 6 t ha^{-1} + 50% RDF ($N_{12}P_{22}K_{10}$ kg ha^{-1})	8.55	91.5	0.56	1.09
T_{10}: VC @ 8 t ha^{-1} + 50% RDF ($N_{12}P_{22}K_{10}$ kgha^{-1})	8.75	89.3	0.54	1.45
LSD at 5%	**0.24**	**0.16**	**0.05**	**0.87**

Macronutrients content in post-harvest soil

The concentration and uptake of macronutrients N, P, K and S in the post-harvest soil of mung bean plant cultivated pots are presented in Table 9. The variation among N, P, K and S values was significant

($p \leq 0.05$). The maximum amounts of nitrogen (171.25 ppm), phosphorous (529.35 ppm), potassium (108.60 ppm) and sulphur (115.20 ppm) in the post-harvest soil were observed in T_6 ($N_{25}P_{45}K_{20}$ kg ha^{-1}) followed by remaining treatments.

Table 9. Effects of vermicompost and available NPK fertilizer on the macronutrient nitrogen (N), phosphorous (P), potassium (K) and Sulphur (S) concentrations (ppm) of the post-harvest soil.

Treatments	N	P	K	S
T_1: Control (-VC & -NPK)	163.13	396.57	99.60	98.58
T_2: VC @ 2 t ha^{-1}	158.63	369.93	90.60	97.03
T_3: VC @ 4 t ha^{-1}	153.13	364.67	90.10	96.38
T_4: VC @ 6 t ha^{-1}	154.13	295.52	93.10	86.83
T_5: VC @ 8 t ha^{-1}	142.50	365.29	102.10	97.33
T_6: $N_{25}P_{45}K_{20}$ kg ha^{-1} RDF (Recommended dose of inorg. fertilizer)	171.25	529.35	108.60	115.20
T_7: VC @ 2 t ha^{-1} + 50% RDF ($N_{12}P_{22}K_{10}$ kg ha^{-1})	153.13	468.88	104.60	97.93
T_8: VC @ 4 t ha^{-1} + 50% RDF ($N_{12}P_{22}K_{10}$ kg ha^{-1})	155.00	398.47	104.10	90.73
T_9: VC @ 6 t ha^{-1} + 50% RDF ($N_{12}P_{22}K_{10}$ kg ha^{-1})	131.25	329.78	98.10	75.53
T_{10}: VC @ 8 t ha^{-1} + 50% RDF ($N_{12}P_{22}K_{10}$ $kgha^{-1}$)	135.75	272.69	91.60	81.78
LSD at 5%	**1.57**	**1.84**	**0.95**	**0.85**

This investigation showed that T_{10} (VC @ 8 ton ha^{-1}+50% RDF-$N_{12}P_{22}K_{10}$ kg ha^{-1}) significantly affected mung bean growth, yield, mineral nutrient accumulation, and protein content. Therefore, to ensure higher mung bean production while maintaining soil health, increasing productivity, and enhancing soil sustainability, the rate of 8 ton vermicompost ha^{-1} plus 50% RDF ($N_{12}P_{22}K_{10}$ kg ha^{-1}) may be suggested to us.

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