Effect of Farm Yard Manure (FYM), Phosphorous Solubilizing bacteria (PSB) and Sulphur on Growth and Yield of Mungbean [Vigna radiata (L.) Wilckzek] along with Soil Sustainability

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Effect of Farm Yard Manure (FYM), Phosphorous Solubilizing bacteria (PSB) and Sulphur on Growth and Yield of Mungbean [*Vigna radiata* (L.) Wilckzek] along with Soil Sustainability

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ABSTRACT

An experiment was conducted during 2020 to investigate the effect of farm yard manure (FYM), phosphorous solubilizing bacteria (PSB) and Sulphur on the growth and yield of mungbean along with soil sustainability. The various treatments applied to mungbean were control i.e., RDF (T_1), RDF + FYM @ 5 tons ha^{-1} (T_2), RDF + FYM @ 5 tons ha^{-1} + PSB (T_3), RDF + FYM @ 5 tons ha^{-1} + PSB+ 40 kg Sulphur (T_4), 125% RDF (T_5), 125% RDF + FYM @ 5 tons ha^{-1} (T_6) and 125% RDF + FYM @ 5 tons ha^{-1} + PSB (T_7). Significantly higher growth parameters like plant height, number of branches plant^{-1}, dry matter accumulation plant^{-1}, number of nodules plant^{-1} was observed with 125% RDF + FYM @ 5 tons ha^{-1} + PSB (T_7). Significantly higher yield parameters like number of pods plant^{-1}, number of seeds pod^{-1}, test weight, seed and stover yield and protein content was also observed with 125% RDF + FYM @ 5 tons ha^{-1} + PSB (T_7). Soil sustainability in terms of soil pH, EC, organic carbon, NPK availability and uptake was also noticed significantly superior in T_7.

Key words: *Vigna radiata*, Phosphorus solubilizing bacteria (PSB), FYM, Growth, Yield, Nutrient uptake

Pulses are an important source of dietary protein throughout the world. As per the World Health Organization (WHO) and FAO per capita per day requirement of pulse in the human diet is 80g, but the production and availability of pulses declined, which is a serious concern in the present scenario. By contributing 25.5% of total global pulse production, India ranks first in both production as well as consumption of pulses at the global level. Apart from those pulses are important for farming system sustainability because of their roles in atmospheric nitrogen fixation with the help of symbiotic bacteria like *Rhizobium.* Mungbean (*Vigna radiata* L.) is one of the third most important pulse crops in India after chickpea and pigeon pea. It is an outstanding source of protein (25%) with higher content of lysine (460 mg/g) and tryptophan (60 mg/g). In India, the pulses are cultivated mainly in rainfed conditions. In 2017-18 total pulse production was 25.23 million tonnes from 29.99 million ha area (Directorate of Economics and Statistics). In the year 2017-18 total area under mungbean in India was 4.1 million ha with an overall production of 1.9 million tonnes (Ministry of Agriculture and Family Welfare). More than 80 per cent of mungbean production comes from Rajasthan, Madhya Pradesh, Maharashtra, Bihar, Karnataka, TN, Gujarat, Andhra Pradesh, Odisha and Telangana. The total area under Mungbean during the 11th plan was 33.32 lakh ha, whereas it was decreased to 30.41 lakh ha during the 12th plan and productivity was 468 kg ha^{-1} [1]. Organic manure like FYM is well recognized for improving macro and micronutrients availability. It provides 0.5% N, 0.2% P_2O_5 and 0.5% K_2O. It improves soil health through its beneficial effect on amending the physical, chemical and biological properties of soil. FYM facilitates in proper aeration and water holding capacity of the soil and helps in the more efficient utilization of chemical fertilizers. Apart from that, it helps in increasing the population of soil micro-organisms that enhances the availability of plant nutrients in the soil. Insoluble reserves of phosphorus are made available to plants after solubilization by PSB like Pseudomonas and Bacillus. Beneficial microbes' resident to the rhizosphere are receiving greater attention, as they can solubilize inorganic phosphate into soluble form through the process of acidification, chelation, exchange reactions and production of organic acids [2]. In addition, these phosphate solubilizing microorganisms (PSMs) can also increase the growth of plants by other mechanisms i.e., production of phytohormones such as IAA [3] which promotes plant growth. Fungi were more efficient than bacteria in solubilizing insoluble phosphate [4]. Although, strains of *Aspergillus* and *Penicillium* spp. are the most common fungi

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capable of phosphorus solubilization but they are less in number in the rhizosphere. Sulphur improves the quality of food crops, particularly legumes. Sulphur containing amino acids like Cysteine and Methionine, which act as a building block in protein synthesis. It plays important role in increasing chlorophyll formation and aiding photosynthesis. Apart from that, it also activates various enzymes and helps in the synthesis of nucleic acids and biotin and thiamine. Under this background, the present experiment was undertaken to analyze the effect of farm yard manure (FYM), Phosphorous Solubilizing bacteria (PSB) and Sulphur on the growth and yield of mungbean along with soil sustainability.

MATERIALS AND METHODS

A field experiment was conducted in *zaid* season (2020) at the agricultural farm of Udai Pratap Autonomous College, which was sandy loam in texture, slightly saline and non-alkaline in reaction. The initial physicochemical properties of experimental soil were bulk density 1.42 g cm^{-3}, particle density 2.65 g cm^{-3}, pH (1:2.5) 7.70, EC 0.75 dSm^{-1}, organic carbon 0.43%, available nitrogen 223.25 kg ha^{-1}, available phosphorus 16.00 kg ha^{-1} and available potassium 209.38 kg ha^{-1}. The various treatments applied to mungbean were control i.e., RDF (T_1), RDF + FYM @ 5 tons ha^{-1} (T_2), RDF + FYM @ 5 tons ha^{-1} + PSB (T_3), RDF + FYM @ 5 tons ha^{-1} + PSB+ 40 kg Sulphur (T_4), 125% RDF (T_5), 125% RDF+ FYM @ 5 tons ha^{-1} (T_6) and 125% RDF + FYM @ 5 tons ha^{-1} + PSB (T_7). The treatments were applied in a randomized block design (RBD) with three replications. The recommended dose for mungbean was 20 kg N ha^{-1}, 40 kg P_2O_5 ha^{-1}, 20 kg K_2O ha^{-1}. Nitrogen was supplied from urea as 50% basal, remaining 50% as topdressing at branching stage. The full dose of P and K through single super phosphate and muriate of potash were applied at the time of sowing as basal dressing. PSB was inoculated @ 200 g/10 kg with a 10% solution of Jaggery as a sticker. Mungbean seeds were sown at the rate of 20 kg ha^{-1}. Sowing was done in line with a spacing of 30 × 10 cm^2. Soil samples from 0-15 cm depth were collected in a plastic bag from individual plots at 30, 60 and 90DAS of the crop. The soil sample of each plot was air-dried, processed to pass through a 2 mm round hole sieve and analysed for oxidizable organic carbon (1*N* $K_2Cr_2O_7$), available N (0.32% alkaline $KMnO_4$ oxidizable), P (0.5 M $NaHCO_3$ extractable), K (1 *N* neutral ammonium acetate extractable) and S (0.15% $CaCl_2$) following the methods described by Walkley and Black [5], Subbiah and Asija [6], Olsen's *et al.* [7], Hanway and Heidel [8] and Williams and Steinbergs [9], respectively. Soil pH was determined in 2:1 soil: water suspension with the help of glass electrode in digital pH meter and electrical conductivity of soil was measured in the supernatant liquid of soil water suspension (1:2) by conductivity bridge [10]. Bulk density in undisturbed samples collected with metal cores of 4.2 cm diameter and 5.8 cm height was measured [11]. Five plants were marked randomly in each replicated plot and plant height was measured from the base of the plant to the tip of the uppermost latest leaf for calculating mean plant height at 30, 60 and 90 DAS. The number of branches of selected plant for height was counted and the average was obtained per plant. The number of pods from marked plants was recorded in each plot and designated as the mean number of pods per plant. After harvesting and threshing, the weight of the grain was recorded. The straw yield was calculated by subtracting grain yield from biological yield. The data collected from the field and laboratory were analyzed statistically using the standard procedure of randomized block design [12]. Critical difference (C.D.) and standard error of the mean (SEM) were calculated to determine the significance among treatment means.

RESULTS AND DISCUSSION

Growth performance of mungbean under different levels FYM, PSB and S application

Plant height

The results obtained concerning the effect of FYM, PSB and Sulphur under mungbean plant height at different growth stages are presented in (Table 1). Application of FYM, PSB and Sulphur alone or in combination significantly increased plant height in comparison to other treatments. From results, it is also evident that the plant height of mungbean increased continuously with advancement in growth stages. Plant height among all treatments was found in the order of $T_7 > T_6 > T_5 > T_4 > T_3 > T_2 > T_1$. The average plant height under T_1, T_2, T_3, T_4, T_5, T_6 and T_7 treatments at 30 DAS were 24.36, 24.63, 25.11, 25.44, 27.15, 31.13, and 31.88 cm and at 60 DAS were 34.89, 35.27, 35.96, 36.44, 38.88, 44.57 and 45.66 cm and at 90 DAS were 36.00, 37.42, 38.18, 38.69, 41.35, 45.56, and 47.74 cm, respectively. The higher application rate of RDF along with FYM and PSB significantly increased the plant height and maximum plant height was recorded under treatment T_7 (RDF 125% +5 tonne FYM ha^{-1} + PSB) in comparison to other treatments. This treatment proved its superiority in comparison to control (T_1) for plant height by about 30.87, 30.86 and 24.59% at 30, 60 and 90 DAS, respectively. This might be due to more profuse vegetative growth lead by the availability of more nutrients in comparison to other treatments from inorganic fertilizers, decomposition of FYM and solubilization of phosphorus by PSB [13-15].

Number of branches plant^{-1}

The observations recorded for the number of branches plant^{-1} have been presented in (Table 1). Application of FYM, PSB and Sulphur alone or in combination significantly increased the number of branches plant^{-1}in comparison to other treatments. From the results, it is also evident that the number of branches plant^{-1} of mungbean increased continuously with advancement in growth stages. Maximum number of branches plant^{-1} at 30 DAS were found with the treatment T_7 followed by $T_6 > T_5 > T_4 > T_3 > T_2 > T_1$. Values of number of branches plant^{-1} under T_1, T_2, T_3, T_4, T_5, T_6 and T_7 treatments were observed as 3.94, 4.09, 4.33, 4.47,4.59, 6.04 and 6.12 at 30 DAS were 7.23, 7.50,7.95, 8.20, 8.43, 11.09, and 11.22 at 60 DAS were7.83, 8,12, 8,60, 8.87, 9.12, 12.00, and 12.15. The higher application rate of FYM PSB and Sulphur significantly increased the number of branches plant^{-1}. This might be due to the availability of more nutrients under T_7 which led to maximum vegetative growth and number of branches plant^{-1}. This treatment proved its superiority in comparison to control (T_1) for the number of branches plant^{-1} by about 55.32, 55.18 and 55.17 % at 30, 60 and 90 DAS, respectively. The favourable effects of a higher application rate of RDF along with FYM and PSB on the number of branches plant^{-1} of legumes were also reported by [16-18].

Dry matter accumulation plant^{-1}(g)

The observations recorded concerning to dry matter accumulation per plant^{-1} have been presented in (Table 1). Application of FYM, PSB and Sulphur alone or in combination significantly increased dry matter accumulation plant^{-1}in comparison to other treatments. From the results, it is also evident that the dry matter accumulation plant^{-1}of mungbean increased continuously with advancement in growth stages. Maximum dry matter accumulation plant^{-1} at 30 DAS were found with the treatment T_7 followed by $T_6 > T_5 > T_4 > T_3 > T_2 > T_1$. Values of dry matter accumulation plant^{-1} under T_1, T_2, T_3, T_4, T_5, T_6 and T_7 treatments were observed as 11.26, 11.64, 11.94, 14.87, 15.74, 20.49, 21.48 g at 30 DAS and 17.34, 17.92, 18.39, 22.90, 24.24, 31.56, 33.08 g at 60 DAS and 21.28, 21.99, 22.57, 28.10, 29.75, 38.73 and 40.60 g at 90DAS. The higher application rate of RDF along with FYM and PSB significantly increased the dry matter accumulation plant^{-1}. This might be due to the availability of more nutrients under T_7 which led to maximum vegetative growth and dry matter accumulation plant^{-1}. This treatment proved its superiority in comparison to control (T_1) for dry matter accumulation plant^{-1} by about 90.76, 90.77 and 99.78 % at 30, 60 and 90 DAS, respectively [19-20].

Table 1 Growth performance of mung bean under different levels FYM, PSB and S application

Treatments	Plant height (cm)			Number of branches plant^{-1}			Dry matter accumulation plant^{-1} (g)			Number of nodules plant^{-1}		
	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS
T_1: RDF	24.36	34.89	36.00	3.94	7.23	7.83	11.26	17.34	21.28	13.98	20.07	24.39
T_2: RDF + FYM @ 5 ton ha^{-1}	24.63	35.27	37.42	4.09	7.50	8.12	11.64	17.92	21.99	14.46	20.75	25.23
T_3: RDF + FYM @ 5 ton ha^{-1} + PSB	25.11	35.96	38.18	4.33	7.95	8.60	11.94	18.39	22.57	15.26	21.90	26.62
T_4: RDF + FYM @ 5 ton ha^{-1} + PSB + 40kg S	24.44	36.44	38.69	4.47	8.20	8.87	14.87	22.90	28.10	16.53	23.72	28.84
T_5: 125% RDF	27.15	38.88	41.35	4.59	8.43	9.12	15.74	24.24	29.75	17.12	24.57	29.87
T_6: 125% RDF+ FYM @ 5 ton ha^{-1}	31.13	44.57	45.56	6.04	11.09	12.00	20.49	31.56	38.73	19.89	28.54	34.70
T_7: 125% RDF + FYM @ 5 ton ha^{-1} + PSB	31.88	45.66	47.74	6.12	11.22	12.15	21.48	33.08	40.60	20.20	28.98	35.24
SEm±	0.131	0.131	0.001	0.051	0.146	0.092	0.066	0.108	0.864	0.38	0.02	0.07
CD (0.05)	0.040	0.040	0.003	0.146	0.451	0.283	0.205	0.334	0.197	1.16	0.05	0.22

Number of nodules plant^{-1}

The observations related to the number of nodules plant^{-1} were recorded in (Table 1). The application of FYM, PSB and Sulphur significantly increased the number of nodules as compared to other treatments. From the results, it is also evident that the number of nodules plant^{-1} increased continuously with advancement in growth stages. The number of nodules among all treatments was found in the order $T_7>T_6>T_5>T_4>T_3>T_2>T_1$. The average number of nodules plant^{-1} in T_1, T_2, T_3, T_4, T_5, T_6 and T_7 treatments at 30 DAS were 13.98, 14.46, 15.26, 16.53, 17.12, 19.89 and 20.20 and at 60 DAS were 20.07, 20.75, 21.90, 23.72, 24.57, 28.54 and 28.98 and at 90 DAS were 24.39, 25.23, 26.62, 28.84, 98.87, 34.70 and 35.24 respectively. The higher application rate of RDF along with FYM and PSB significantly increased the number of nodules per plant and the maximum number was recorded under treatment T_7 (RDF 125% ha^{-1} + 5 tonne FYM ha^{-1} + PSB) in comparison to other treatments. This treatment proved its superiority in comparison to control (T_1) for the number of nodules plant^{-1} by about 44.49, 44.39 and 30.78% at 30, 60 and 90 DAS, respectively. This might be due to increased growth rate and root development at a higher amount of application [21].

Yield performance of mungbean under different levels FYM, PSB and S application

Number of pods plant^{-1}

The effects of different treatments on the number of pods plant^{-1} were presented in (Table 2). The results showed a significant effect of treatments in comparison to control. Maximum number of pods were recorded in T_7 (25.07) followed by other treatments T_6 (24.25) > T_5 (22.82) > T_4 (21.88) > T_3(21.20) > T_2(21.10) >T_1 (20.74). Application of FYM and PSB significantly increased the number of pods plant^{-1} and the maximum number of nodules plant^{-1} was recorded under treatment T_7 (RDF 125% ha^{-1} +5tonne FYM ha^{-1} +PSB) in comparison to other treatments and this might be due to higher vegetative growth led by nutrient enrichment of the soil. This treatment proved its superiority in comaprison to control (T_1) for the number of pods plant^{-1} by about 20.87%. A significantly higher number of pods plant^{-1} along with phosphorus solubilizing bacteria (PSB) like *Aspergillus awamori, Psuedomonas striata* [22] also observed the maximum number of pods plant^{-1} with the treatments which received the higher application of FYM [23].

Number of seeds pod^{-1}

The effects of different treatments on the number of seeds per pod^{-1} were recorded and presented in (Table 2). Increasing the application rate of FYM PSB and Sulphur increased the number of seeds pod^{-1}and the maximum number of seeds pod^{-1} was obtained in treatment T_7 (125% RDF + 5tonnes FYMha^{-1} + PSB). The maximum number of seeds per pod was recorded in treatment T_7 (8.96) followed by other treatments T_6 (8.87)>T_5 (8.38)> T_4 (8.26) >T_3 (7.41) >T_2 (6.87)>T_1 (6.85). T_7 (125% RDF + 5 tonnes FYM ha^{-1} + PSB) proved its superiority over control i.e., T_1 for the number of seeds pod^{-1} by about 30.80%. It is clear from the result that the application of FYM PSB and Sulphur significantly increased the number of seeds per pod^{-1} [24].

Test weight (g)

The effects of different treatments on the test weight of mungbean are presented in (Table 2). Increasing the application rate of FYM PSB and Sulphur significantly increased test weight and the maximum value of test weight was obtained in treatment T_7 (125% RDF + 5 tonne FYM ha^{-1} + PSB. The maximum test weight was recorded in treatment T_7 (37.35) followed by other treatments T_6 (36.40)>T_5 (35.02)> T_4 (37.22) >T_3 (33.31) >T_2 (34.05)>T_1 (32.99). T_7 (125% RDF + 5 tonnes FYM ha^{-1} + PSB) proved its superiority over control i.e., T_1 for test weight by about 13.21%. It is clear from the result that the application of FYM PSB and Sulphur significantly increased the test weight [24].

Table 2 Yield performance of mung bean under different levels FYM, PSB and S application

Treatments	No. of pods plant^{-1}	No. of seeds pod^{-1}	Test weight (g)	Seed yield (q ha^{-1})	Stover yield (q ha^{-1})	Protein content (%)
T_1: RDF	20.74	6.85	32.99	8.26	23.76	23.47
T_2: RDF + FYM @ 5 ton ha^{-1}	21.10	6.87	34.05	8.74	24.49	23.50
T_3: RDF + FYM @ 5 ton ha^{-1} + PSB	21.20	7.41	33.31	9.44	25.08	23.69
T_4: RDF + FYM @ 5 ton ha^{-1} + PSB + 40kg S	21.88	8.26	37.22	9.73	26.48	23.71
T_5: 125% RDF	22.82	8.38	35.02	10.17	26.69	24.19
T_6: 125% RDF+ FYM @ 5 ton ha^{-1}	24.25	8.87	36.40	11.02	28.54	24.76
T_7: 125% RDF + FYM @ 5 ton ha^{-1} + PSB	25.07	8.96	37.35	12.07	29.79	25.69
SEm±	0.0281	0.034	0.003	0.015	0.013	0.002
CD (0.05)	0.0670	0.106	0.011	0.466	0.040	0.006

Seed and stover yield (q ha^{-1})

The effects of different treatments on seed and stover yield of mungbean are presented in (Table 2). The Application of FYM PSB and Sulphur significantly increased the seed and stover yield in comparison to control. Maximum seed and stover yield was recorded in T_7 (125% RDF + 5 tonne FYM ha^{-1} + PSB). The seed yield of mungbean under different treatments were T_7 (12.07 q ha^{-1}) >T_6 (11.02q ha^{-1}) >T_5 (10.17 q ha^{-1}) >T_4 (9.73 q ha^{-1}) >T_3 (9.44 q ha^{-1}) >T_2 (8.74 q ha^{-1}) >T_1 (8.26 q ha^{-1}), respectively. Stover yield of mungbean under different treatments were observed as T_7 (29.79 q ha^{-1}) >T_6 (28.54q ha^{-1}) >T_5 (26.69 q ha^{-1}) >T_4 (26.48 q ha^{-1}) >T_3 (25.08 q ha^{-1}) >T_2 (24.49 q ha^{-1}) >T_1 (23.76 q ha^{-1}), respectively). T_7 (125% RDF + 5 tonnes FYM ha^{-1} + PSB) proved its superiority over control i.e., T_1 for seed and stover yield by about 46.12 and 20.24%, respectively [25-26].

Protein content (%)

The effects of different treatments on the protein content of mungbean are presented in (Table 2). Increasing the application rate of FYM PSB and Sulphur significantly increased the protein content in comparison to control and maximum protein content was obtained in treatment T_7 (125% RDF + 5 tonne FYM ha^{-1} + PSB). The maximum protein content were recorded in treatment T_7 (25.69) followed by other treatments T_6 (24.76)>T_5 (24.19)> T_4 (23.71) >T_3 (23.69) >T_2 (23.50)>T_1 (23.47). T_7 (125% RDF + 5 tonnes FYM ha^{-1} + PSB) proved its superiority over control i.e., T_1 for protein content by about 9.45%. It is clear from the result that the application of FYM PSB and Sulphur significantly increased the protein content [27].

Post crop soil fertility status, nutrients availability and uptake by mungbean under different levels FYM, PSB and S application

Soil pH and EC

The results related to the effect of different treatments containing FYM PSB and Sulphur on soil pH and EC after harvesting of crop is presented in (Table 3). As evident from the result that soil pH and EC significantly decreased in comparison to control with an increase in the application rate of FYM, PSB and Sulphur. A maximum decline in soil pH and EC in comparison to control was noticed in T_7 [28]. A decrease in soil pH with the maturity of the crop might be due to organic matter accumulation and its decomposition. The decline in soil EC might be due to an increase in nutrient uptake by crops with the growth stage. During the cultivation of legumes, the soil is acidified due to proton release from roots [29].

Organic carbon content (%)

The results related to the organic carbon status of soil under different treatments after harvesting mungbean are presented in (Table 3). The organic carbon content of soil increased significantly in comparison to control with the application of FYM PSB and Sulphur. Concerning soil organic carbon content, various treatments could be arranged in the order T_7> T_6> T_5> T_4> T_3> T_2>T_1. Treatment T_7 was found to be having significantly higher organic carbon in comparison to other treatments and this might be due to more organic matter accumulation led by more vegetative growth [30].

Available nitrogen (kg ha^{-1})

The data regarding the available nitrogen status of soil after harvesting mungbean under various treatments are presented in the (Table 3). Soil available nitrogen content significantly increased with the application of FYM PSB and Sulphur. The effect of different treatments regarding available nitrogen status was observed in the order of T_7>T_6> T_5> T_4> T_3> T_2>T_1, where the available nitrogen status of soil was 255.36, 248.25, 240.52, 237.82, 235.88, 232.20 and 227.54kg ha^{-1} respectively. T_7 (125% RDF + 5 tonnes FYM ha^{-1} + PSB) proved its superiority over control i.e., T_1 for soil nitrogen availability by about 12.22%. This might be due to more availability of nitrogen led by biological nitrogen fixation under legume crops [31].

Available phosphorus (kg ha^{-1})

The data about the effect of FYM PSB and Sulphur on soil available phosphorus status of soil after harvesting mungbean is presented in (Table 3). Soil available phosphorus content significantly increased with the increased application of FYM PSB and Sulphur in comparison to control. Available phosphorus status of soil among different treatments was found in the order $T_7>T_6>T_5>T_4>T_3>T_2 > T_1$ and the values of different treatments were 20.66, 20.16, 19.46, 19.27, 19.17, 19.19 and 19.00 kg ha^{-1} under respective treatments. T_7 (125% RDF + 5tonnes FYM ha^{-1} + PSB) proved its superiority over control i.e., T_1 for soil phosphorus availability by about 8.73%. This might be due to the decomposition of organic matter in the form of FYM and solubilization of insoluble form of phosphorus by application of P solubilizing bacteria [32].

Available potassium (kg ha^{-1})

The data relating to the effect of application of FYM PSB and Sulphur on available potassium content of the soil after harvesting mungbean is presented in (Table 3). Soil available potassium content significantly increased in comparison to control with the application of FYM PSB and Sulphur. Available potassium status of soil among the treatments were found in the order $T_7> T_6> T_5> T_4> T_3> T_2> T_1$ and the values of the 188.15, 183.27, 177.22, 176.34, 175.30, 170.00 and 167.03 kg ha^{-1} under respective treatments. T_7 (125% RDF +5tonnes FYMha^{-1} + PSB) proved its superiority over control i.e., T_1 for soil potassium availability by about 12.64%. This might be due to the enrichment of soil in potassium due to the decomposition of FYM along with supply from inorganic fertilizers [33].

Nitrogen uptake (kg ha^{-1})

The data concerning nitrogen uptake by mungbean under different treatments are presented in (Table 3). Nitrogen uptake by the mungbean (grain and stover) was increased significantly with the application of FYM PSB and Sulphur over control. The effect of various treatments on nitrogen uptake (seed and stover) was found in the order of $T_7>T_6>T_5>T_4>T_3>T_2 >T_1$. Among various treatments, the uptake of N by seed and stover varied from 34.85 to 48.20 kg ha^{-1} and 39.93 to 51.00 kg ha^{-1}respectively. T_7 (125% RDF + 5 tonnes FYM ha^{-1} + PSB) proved its superiority over control i.e., T_1 for nitrogen uptake by about 38.30 and 27.72 % for seed and stover respectively. This might be due to more availability of nitrogen from the higher application rate of inorganic fertilizers and decomposition of FYM [34].

Table 3 Post crop soil fertility status, nutrients availability and uptake by mung bean under different levels FYM, PSB and S application

Treatments	Soil pH	EC (dSm^{-1})	Organic carbon content (%)	Nutrients availability (kg ha^{-1})			N uptake (kg ha^{-1})		P uptake (kg ha^{-1})		K uptake (kg ha^{-1})	
				N	P	K	Seed	Stover	Seed	Stover	Seed	Stover
T_1: RDF	8.00	0.35	0.50	227.54	19.00	167.03	34.85	39.93	10.16	10.27	12.20	30.51
T_2: RDF + FYM @ 5 ton ha^{-1}	7.92	0.34	0.51	232.20	19.19	170.00	35.74	42.10	10.42	10.83	12.87	32.16
T_3: RDF + FYM @ 5 ton ha^{-1} + PSB	7.87	0.33	0.51	235.88	19.17	175.30	36.88	42.71	10.76	10.98	13.05	32.63
T_4: RDF + FYM @ 5 ton ha^{-1} + PSB + 40kg S	7.65	0.32	0.52	237.82	19.27	176.34	37.53	43.70	10.95	11.24	13.35	33.39
T_5: 125% RDF	7.53	0.33	0.53	240.52	19.46	177.22	38.08	44.30	11.11	11.39	13.54	33.85
T_6: 125% RDF+ FYM @ 5 ton ha^{-1}	7.47	0.34	0.55	248.25	20.16	183.27	42.13	47.46	12.29	12.20	14.50	36.26
T_7: 125% RDF + FYM @ 5 ton ha^{-1} + PSB	7.40	0.32	0.56	255.36	20.66	188.15	48.20	51.00	14.06	13.11	15.59	38.96
SEm±	0.44	0.02	0.01	0.611	0.307	1.250	0.01	0.01	0.03	0.02	0.02	0.22
CD (0.05)	1.36	0.06	0.02	1.884	0.947	3.852	0.04	0.03	0.09	0.06	0.05	0.69

Phosphorus uptake (kg ha^{-1})

The data relating to phosphorus uptake under different treatments by mungbean is presented in (Table 3). It is evident from the table that the application of FYM PSB and Sulphur under different treatments proved a significant increase in phosphorus uptake by seed and stover as compared to control (T_1). The effect of various treatments on phosphorus uptake could be arranged in the order of $T_7>T_6>T_5>T_4>T_3>$ T2 and T_1. The effect of T_7 was found to be significantly superior over other treatments. The phosphorus uptake ranged from 10.16 to14.06 kg ha^{-1} for seed and from 10.27 to 13.11 for stover. T_7 (125% RDF + 5 tonnes FYM ha^{-1} + PSB) proved its superiority over control i.e., T_1 for phosphorus uptake by about 38.38 and 27.65 % for seed and stover respectively. This might be due to more availability of nitrogen from the higher application rate of inorganic fertilizers and decomposition of farm yard manure (FYM) [35].

Potassium uptake (kg ha^{-1})

The data obtained in respect of potassium uptake by mungbean under different treatments are presented in (Table 3). Potassium uptake by the mungbean was increased significantly with the addition of FYM PSB and Sulphur over control. The effect of various treatments on potassium uptake by seed and stover was found in the order of T_7>T_6>T_5>T_4>T_3 >T_2 >T_1. Among various treatments, the uptake of K by seed and stover varied from 12.20 to 15.59 kg ha^{-1} and 30.51 to 38.96 kg ha^{-1}respectively. The effect of T_7 was found to be significant over all the treatments. T_7 (125% RDF + 5 tonnes FYM ha^{-1} + PSB) proved its superiority over control i.e., T_1 for phosphorus uptake by about 27.78 and 37.96% for seed and stover respectively. This might be due to more availability of nitrogen from the higher application rate of inorganic fertilizers and decomposition of FYM [36].

CONCLUSION

From this experiment, it is concluded that the application of RDF 125% ha^{-1} + 5 tonnes farm yard manure ha^{-1} + Phosphorus solubilizing bacteria is superior for the production of mungbean along with maintaining soil sustainability.

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