RESEARCH ARTICLE

Field Application Study using Vermicompost, *Rhizobium* and Farm Yard Manure as Soil Supplements to Enhance Growth, Yield and Quality of *Glycine max*

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ABSTRACT: Improving soil fertility for sustainable agriculture and crop production has received popular attention. The need to avoid food shortages for the growing population and achieve sustainable development goals is the first priority of researchers. To meet this challenge, importance is now being placed on the incorporation of organic manures for the rejuvenation of soil health and increased productivity in agriculture. The use of vermicompost, biofertilizers, and natural manures helps to enhance the physical, chemical, and biological properties of the soil. Vermicomposting is a biotechnological process that can be used to produce high-quality manure for successful agricultural production. A field application study was conducted using vermicompost, *Rhizobium* - a biofertilizer, and farm yard manure (FYM) to determine soil physico-chemical and biological properties, growth parameters, nodulation, and yield of soybean (Glycine max) in south Tamil Nadu, India. The selection of the crop and manure is of prime importance because of the enhancement of soil productivity in terms of nitrogen availability and the increased presence of micronutrients in the soil. Soybean have rich protein source, and their nodulation fixes nitrogen to improve the soil's fertility. The organic manures support the growth and multiplication of soybean and proliferate the beneficial microbial population in the soil. The present study evidenced all the expected quality parameters and the maximum soybean yield of 1.85 tons per hectare, which was obtained from a vermicompost applied plot when compared to other manure applied plots. The physico-chemical properties and microbial count of the soil were significantly increased during the application of vermicompost and biofertilizer compared to the application of FYM.

KEYWORDS: *Lampito mauritii*, *Rhizobium* Farm Yard Manure, *Glycine max*, vermicompost, soil properties, soybean growth parameters

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1. INTRODUCTION

Soil is a dynamic, living natural entity and plays a key role in terrestrial ecosystems. The components of soil include inorganic mineral matter like sand, silt and clay particles, organic matter, water, gases and living organisms such as earthworms, insects, bacteria, fungi, algae and nematodes. There is a continual interchange of molecules and ions between the solid, liquid and gaseous phases that are mediated by physical, chemical and biological processes. The importance of microbial component of soil is often overlooked, because it is largely invisible to the naked eye. However, essential parts of the global Carbon (C), Nitrogen (N), Phosphorous (P), Sulphur (S) and water cycles are carried out in soil largely through microbial and faunal interactions with the physical and chemical properties of the soil. Soil organic matter is a

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major terrestrial pool for C, N, P and S and the cycling and availability of these elements are constantly being altered by microbial mineralization and immobilization. Inorganic constituents of soil play a major role in retaining cations (through ion exchange) and non polar organic compounds and anions (through sorption reactions). Soil also serves as an essential reservoir of water for terrestrial plants and microorganisms and as a purifying medium through which water passes. Sustainability was achieved in soil fertility to improve agricultural production, organic waste recycling of farm wastes and kitchen wastes. Animal manures and sewage sludge are anaerobically treated to get manure which is used for agriculture [1, 2].

Generally organic matter is considered to be a cementing agent that stabilizes the soil structure and decreases soil susceptibility to crust formation and surface sealing. Organic matter content is an important factor in binding the soil particles into water stable aggregates, generally by forming an organo-mineral complex. Sullivan (1990) [3] proposed that organic matter can increase air encapsulation within the soil during water uptake which in turn decreases water uptake rates and prevents slaking and aggregate breakdown.

Earthworm-enabled microbial composting yielded vermicompost is bearing maximum organic contends like organic carbon, available and total nitrogen, phosphorous, potassium and micronutrients by the result of microbiological and enzymatic activities [4-6]. Earthworms are capable of disintegrating organic compounds with the help of abundant microbial load present in the mucus and intestine of the earthworms which act as ecosystem engineer, efficiently recycling the nutrients [7]. Organic agriculture makes farming system and people are dependent on this sector more resilient to climate change due to its water use efficiency, tolerance to extreme weather conditions and lower or no risk of total crop failure [8]. The impact of climate change is found to be more on the agriculture and water usage to achieve zero hunger goal of sustainable development [9].

Glycine max is the important leguminous crop which inhabits many rhizobial species like *Rhizobium*, *Bardyrhizobium*, *Ensifer* (formerly *Sinorhizobium*) and *Mesorhizobium* which are actively fixing nitrogen along with other plant growth promoting substances [10]. It also provides quality protein and oil [11] and globally this crop grown in the six percentage of arable land [12] covers nearly 50 percentage of the area where the legumes are cultivated [13]. Soybean is cultivated as a major crop in the United States of America, Argentina, Brazil, China and India [14].

Organic matter in soil makes it dynamic. It changes continuously as a result of microbial activity. It can therefore be maintained at a reasonable stable level, both in quality and in quantity by means of suitable additions of new organic materials. This is an essential part of good management practice. It involves addition of bulky manures such as farm-yard manures, compost and processed animal wastes. In the present study, we compared the effectiveness of vermicompost, *Rhizobium* - a biofertilizer and farm yard-manure for the field application of soybean that encourages organic farming practices in effective manner.

2. MATERIALS AND METHODS

2.1. Vermicomposting

The raw materials used for vermicomposting are leaf litter and cow dung. The earthworm species engaged for vermicomposting was *Lampito mauritii* – an anecic indigenous species. The vermicompost pits were prepared in the dimension of 2mx2mx1m. The bottom layer was filled with pebbles and sand, which infiltrate the excess water from the composting pit. The second layer was filled with rich garden soil and old compost as inoculums. The earthworms were introduced on the old compost layer. Cow dung and leaf litter were mixed at the rate of 1:2 ratios and added in the pit as a feed for the earthworms. Finally the pit was covered by coconut fronds in order to prevent moisture evaporation by direct sun light and to protect the earthworms from its natural predators. Water was sprinkled once in 2 or 3 days, the contents of the pit were turned once in a week for even decomposition and enhanced aeration. After 60 days the matured compost was collected, sieved and packed for further field application studies.

2.2. Collection of Manures and Biofertilizer

Vermicompost prepared by using indigenous earthworm *Lampito mauritii* and farm yard manure collected from nearby agricultural farm have been taken to the field. Biofertilizer – *Rhizobium* was collected from Agricultural Extension Centre, Alangulam, Tirunelveli District, Tamil Nadu, India. Soybean field trial experiments were carried out using the above materials.

2.3. Field Application Studies

2.3.1. Selection of Field

The field selected is located in Karambai near Kallidalkurichi, Tirunelveli District, Tamil Nadu, India**.** The selected field was leveled and applied with pond silt @ 15 tons per hectare. This is to minimize the residual effect of the chemical fertilizers once used. The plots were made in randomized block design (RBD) manner and triplicates for each treatment were performed.

2.3.2. Crop Selection and Treatments

Field application of organic manures was carried out on soybean crop cultivation. Soybean (*Glycine Max*), family *Fabaceae*, the JS soy bean variety was used for the present study. The field was partitioned into many small plots. The plot size for soybean cultivation was 20 m^2. The plots were put in randomized block design manner. Soil bund was made in between each plot in order to minimize the seepage effect to the maximum possible way. Vermicompost, *Rhizobium* and farm-yard manure were applied as per the recommendations of Tamil Nadu Agricultural University (TNAU).

The following were the treatments for the soybean field application studies:

T1 - Control plot - without application of any manures

T2 - Vermicompost applied plot

T3 - Farm yard manure applied plot

T4 – Biofertilizer - *Rhizobium* applied plot

2.4. Soil Sampling

The soil samples of all the trial plots were collected periodically. Soil sampling was done on 25th day (first stage), 50^{th}day (second stage) and 75th day (third stage). Wedge shaped cuts about half a feet depth were made in the field away from the bunds in different locations of a plot, the soil along the wedge surface was scraped, collected and pooled together. The collected samples were kept in a polythene pack in order to protect the soil flora and maintain the moisture content of the soil.

2.5. Soil Analysis

The collected soil samples were taken for bacterial, fungal and actinomycetes count. After enumeration of microbial count and estimation of moisture content, the collected samples were dried. This was to prevent the evaporation of nutrients from the samples. The physicochemical properties like electrical conductivity, pH, bulk density, porosity, water holding capacity, moisture content, Nitrogen, Phosphorous, Potassium and micro nutrients were analyzed. The following methods were used for the analysis of the samples collected from the field application study.

2.5.1 Physico-chemical properties and microbial analysis

The physical parameters include pH, electrical conductivity (EC) were analyzed by the methods of Jackson [15]. Bulk density (BD) measured by using the methods of Tandon [16]. The methods of Chandrabose *et al.,* [17] were used to measure porosity, moisture content and water holding capacity. Estimation of Nitrogen was carried out by Kjeldahl method, Phosphorus by Colorimetric method, Potassium, Calcium and Magnesium by Flame photometric method, Zinc and Copper by Atomic Absorption Spectroscopy (AAS) were performed [16]. Determination of Iron and Manganese was carried out by Spectrophotometric method [15,18]. Enumeration of bacteria, fungi and actinomycetes were performed to find the microbial count [19].

2.6 Growth parameters of Glycine Max

The sampling of plants was done during 25^{th} day, 50^{th} day and 75^{th} day of crop cultivation. From the triplicate plot, a plant from each plot was randomly picked out carefully and examined for its various growth parameters. From the triplicate for each parameter mean value was calculated. The growth parameters including root length, shoot length, number of nodules, leaves, pods, flowers, buds, fresh and dry weight of the plants were observed. The root length, shoot length, inter nodal length were measured using a scale and recorded in centimeter (cm). The number of nodules, leaves, flowers and pods were counted and recorded in the observation book. Fresh weight of the whole plant was weighed using a digital balance and recorded in grams (g). The dry weight of the whole plant was taken by sun drying them for two days and then keeping them in hot air oven for 12 hours. After that it was weighed by using a balance and recorded in grams (g).

2.7 Statistical analysis

The data collected from experiments of physico-chemical, microbiological parameters of soil and growth parameters of experimental soybean plants were tabulated. The mean and standard error were calculated. The experimental results were tested for its significance by Analysis of Variance (ANOVA).

3. RESULTS AND DISCUSSION

3.1 Physical properties of soil

The physical properties of soybean cultivated soil observed during the application of organic manures are presented in Table 1. The organic manure application enhanced the physical properties of the soil. The observed physical properties are electrical conductivity, pH, and water holding capacity, moisture content, porosity and bulk density. Initial stage observation of physical properties showed that the maximum water holding capacity of 75.67 % was noted in the FYM applied plot (T3), the maximum porosity of 56.4 % was recorded in the vermicompost applied plot (T2). The final stage recorded the maximum water holding capacity of 79.7 % and porosity of 60.03 % were observed the field applied with vermicompost as manure. Krishnamurthy and Ravikumar [20] also reported that the application of cattle manure improved the moisture content and water holding capacity of the soil. The pH ranged from 7.27 to 8.1. The minimum of 7.27 was observed in T2 (vermicompost applied plot) and the maximum of 8.1 in T3 (FYM applied plot). Sarkar and Singh (1997) [21] reported that the sole application of manure decreased the soil pH considerably which corroborates well with our findings (Fig.1). The EC ranged from 1.11 to 1.32 mS/cm. The minimum EC of 1.11 mS/cm was observed in T2 (vermicompost applied plot) and the maximum of 1.32 ± 0.01mS/cm in T3 (FYM applied plot). The analysis of variance (ANOVA) shows that there is a significant difference between the experiments.

Table 1: Physical properties of soybean cultivated soil

Stage	Treatments	WHC (%)	MC (%)	BD (g/cm^3)	Porosity (%)	EC mS/cm	pH
Initial	T1	59.17	36	1.45	39.17	1.32	7.9
	T2	73.07	41.6	1.17	56.4	1.11	7.27
	T3	75.67	48.3	1.19	52.87	1.24	8.1
	T4	68.6	38.3	1.25	52.80	1.22	7.8
Intermediate	T1	61.1	41	1.38	40.5	1.32	7.5
	T2	80.13	63.4	1.15	51.8	1.18	7.27
	T3	73.17	48	1.2	47.7	1.27	7.7
	T4	75.9	60.7	1.16	52.00	1.23	7.6
Final	T1	61.5	41.7	1.36	39.7	1.2	7.5
	T2	79.7	60.5	1.1	60.03	1.18	7.6
	T3	79.2	59.4	1.01	56.7	1.2	7.81
	T4	77.7	71.9	1.11	57.27	1.08	7.27

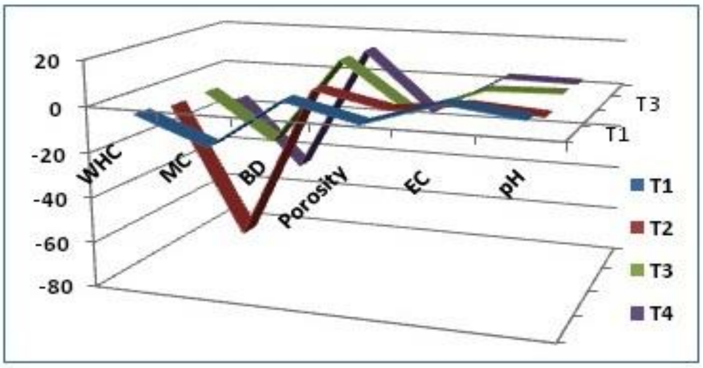

Figure 1: Changes in physical properties from initial to final state of physical properties

3.2 Chemical properties of soil

The result of chemical properties of soybean cultivated soil observed during the field application study is presented in Table 2. The nitrogen, potassium and zinc were found maximum in the vermicompost applied field (T2) and the observed values were 59.67 kg/acre, 255.6 kg/acre and 3.88 ppm respectively during the initial stage of field application studies. The maximum nitrogen content of 51.67 kg/acre with the application of vermicompost, maximum phosphorus of 66.3 kg/acre and potassium of 249.3 kg/acre with the *Rhizobium* applied plot were observed during the final stage of soybean field application studies. The results of ANOVA showed that there is a significant difference between the experiments. Somani and Saxena [22] noticed that there is a considerable increase in available nitrogen status of soil due to the application of farmyard manure. Singh and Srivastava [23] and Prasad et al., [24] also observed that available phosphorus was significantly increased in soil with poultry manure and farmyard manure application. Vermicompost, porous and aerated granules show better water holding capacity, consist of vital macro nutrients nitrogen, phosphorous and potassium (NPK) supporting plant growth in terms of biomass and height of the plants [25].

Table.2: Chemical properties of soybean cultivated soil

Stage	Treatments	N (kg/acre)	P (kg/Acre)	K (kg/acre)	Zn(ppm)	Cu (ppm)	Fe (ppm)	Mn (ppm)	OC (%)
Initial	T1	32	34	185.6	1.93	0.78	15.95	6.08	0.29
	T2	59.67	61.3	255	3.88	0.92	24.5	8.75	0.33
	T3	50.3	55.6	211	3.31	0.89	16.96	8.17	0.23
	T4	38	77.3	243.3	3.08	1.37	27.57	11.9	0.34
Intermediate	T1	30.67	36.7	171.2	1.8	0.74	16.8	6	0.3
	T2	61.6	71	259.67	3.86	1.7	31	12.87	0.35
	T3	61.67	67	220.0	3.33	1.26	24.2	9.07	0.26
	T4	39.3	91.6	251.7	3.61	1.4	30.33	12.83	0.38
Final	T1	20.1	32.7	169	1.58	0.51	15.1	3.8	0.21
	T2	51.67	55.7	233.3	3.99	1.32	28.16	11.62	0.32
	T3	49.3	51.3	210	3.27	1.21	20.9	6.09	0.28
	T4	35.0	66.3	249.3	3.4	1.13	29.6	12.1	0.31

Figure 2 shows the changes in chemical properties from initial to final stage of organic soybean cultivation. Vermicompost is maintaining maximum amount of macro and micronutrients when compared to the FYM applied plot and control plot. Our results corroborate well with the results reported by Yagoub. *et.al.*, [26].

3.3 Microbial Analysis of Soil

The microbial count observed during soybean field application study is reported in Table 3. The maximum count of bacteria, fungal and actinomycetes were recorded in the soil sample from vermicompost applied plot (T2). The observed values were 3.9 x 10^5 CFU/g, 2.33 x 10^3CFU/g and 3.37 x 10^4 CFU/g respectively.

During the intermediate stage of soybean cultivation study, the maximum of bacteria of 4.6 x 10^5 CFU/g with vermicompost applied plot, the maximum actinomycetes count of 4.13 x 10^4 CFU/g observed with the *Rhizobium* applied plot. The final stage is noted maximum bacterial count of 3.17x10^5 CFU/g in vermicompost applied plot (T2) and fungal count of 1.85 10^3 and actinomycetes count of 2.80x10^4 CFU/g. The statistical analysis (ANOVA) of actinomycetes shows that there is a significant difference between the experiments at 5 percent level. The ANOVA of bacterial and fungal count show that there is a significant difference between the experiments at 1 percent level. Lee [27-28] observed that the maximum microbial count is achieved with the application of vermicompost which is well coincided with our present result.

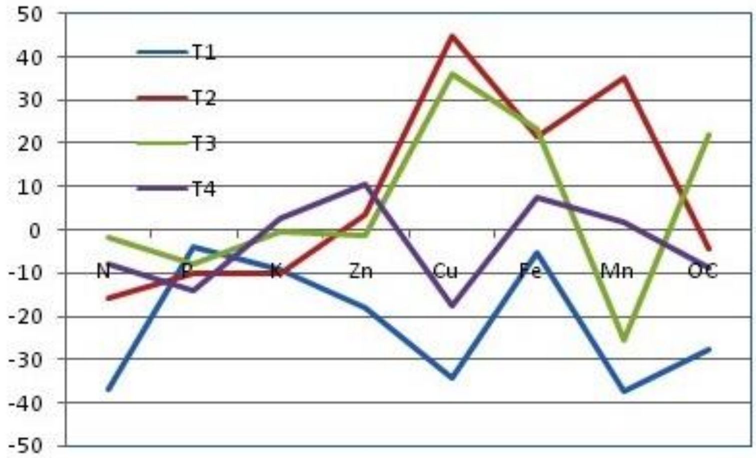

Figure 2: Changes in chemical properties from initial to final stage of chemical properties

Table 3: Microbial count of soybean cultivated soil

Stage	Treatments	Bacteria x 10^5	Fungi x 10^3	Actinomycetes x10^4
Initial	T1	1.73	0.86	1.81
	T2	3.9	2.33	3.32
	T3	3.4	2.1	2.90
	T4	3.4	1.9	3.87
Intermediate	T1	2.27	1.3	1.87
	T2	4.67	2.5	3.7
	T3	4.1	2.8	4.13
	T4	3.87	2.79	3.2
Final	T1	0.99	0.78	1.23
	T2	3.17	1.8	2.37
	T3	2.77	1.85	2.8
	T4	2.5	1.8	2.2

Devi et al., [29] found that soybean cultivation using vermicompost has positively influence on the nodulation by the abundance microbial load in the soil. The retention of abundance of microbial count is observed in the present study (Figure 3). Vijayakumari [30] reported that the microbial load was consistently increased while cultivating soybean using organic manures which is reflected in our field application study using vermicompost and FYM.

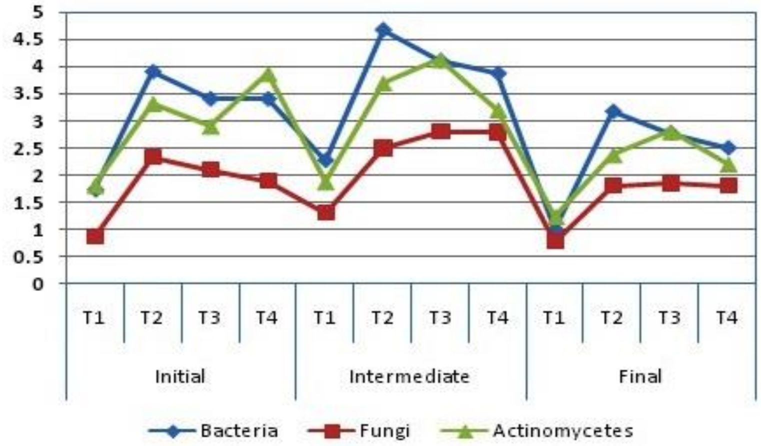

Figure 3: Microbial count observed during soybean field application studies

Table 4: Soybean growth parameters

Stage	Treatments	Root length (cm)	Shoot length (cm)	Inter nodal distance (cm)	No. of leaves	Fresh weight (g)	Dry weight (g)	No. of nodules	No. of flowers	No. of pods
25th day	T1	13.4	16.6	1.6	5.67	6.15	1.6	3.66	-	-
	T2	15.07	18.47	1.5	5.92	6.2	1.6	5.69	-	-
	T3	13.2	15.37	1.53	7.3	10.3	2.58	5.65	-	-
	T4	15.1	18.2	1.9	6.0	8.8	2.23	4.64	-	-
50th day	T1	16.5	19.8	3.13	29.0	17.4	3.4	11.3	12.0	15.0
	T2	26.6	34.4	3.47	31.0	33.7	6.3	12.0	31.0	34.3
	T3	27.9	30.5	2.8	30.3	34.65	4.97	17.3	25.66	40.3
	T4	22.6	30.4	3.2	17.0	38.3	6.08	15.3	31.66	26.3
75th day	T1	18.39	30.65	2.8	27.3	35.1	6.3	6.3	3.68	34.3
	T2	29.5	36.69	3.6	30.3	42.8	7.13	11.0	7.31	45.0
	T3	28.6	34.4	3.7	34	40.6	7.9	14.3	8.0	42.85
	T4	29.2	37.6	4.17	38.6	41.8	7.4	12.0	7.0	57.3

3.4 Growth parameters of soybean

The growth parameters of soy bean observed during the field application studies were tabulated in Table 4. The initial observation on 25th day is that the vermicompost applied plot was recorded and showed maximum shoot length of 18.47 cm and maximum number of leaves and fresh weight were observed in the

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FYM applied plot and the values were 7.3cm and 10.3 g respectively. The 50th day observation of soybean field application studies resulted in the maximum root length, number of nodules and pods with FYM applied plot and the noted values were 27.9 cm, 17.3 and 40.3 respectively. Ramsingh et al., [31] explained that the superiority of FYM is due to the release of aliphatic and aromatic hydroxyl acids, humus and lignin and Singh et al., [32] observed maximum yield with the application of FYM. The application of organic manures increased the dry matter yield [33-34]. The internodal distance of 3.47 cm was observed in the vermicompost applied plants. The maximum number of flowers recorded during the 50th day of soybean filed application study with the *Rhizobium* applied plants and the recorded value is 31.66. The maximum number of leaves was recorded with the application of *Rhizobium* on the 75th day of soy bean field application studies. Vermicompost application increased the root length of 29.5 cm and shoot length of 37.6 cm with the T4 plot which is applied with biofertilizer - *Rhizobium*.

Lobo et al., [35] reported an increase of nodules and dry matter with the usage of sludge. Maximum height of soybean plant growth was observed by Carvalho et al., [36] when the plant is treated with organic manures including poultry manure. Vermicompost application improves the growth and agricultural production and physico chemical properties of soil [37]. Nutrient availability in the soil is enhanced by the application of vermicompost for the healthy crop production [38]. Vermicompost contains growth harmones and fulvic and humic acid can remove the toxic materials from the soil.

Vermicompost have humus content in the form of humic acid (2 to 10%) which can be extracted and used in agriculture [39]. The humic acid increases the benefits to the plant growth and supports the plant to uptake nutrients and helps them overcome plant stress. The presence of humic acid through vermicompost supports soybean growth [40]. In agricultural practices the role of soybean cultivation enhances economic condition of world by providing nitrogen to the agricultural field and prevents the loss of nitrogen and restores the atmospheric nitrogen to the soil. Hungria and Mendes [41] reported that the establishment of soybean in Brazil through the inoculation of *Bradyrhizobium* strain successfully improved the crop yield and amount of nitrogen fixation. Humic substances from vermicompost have complex and bioactive materials which include humic acids, fulvic acid and humin strongly stimulate the rhizospere and growth of the plant tolerate stress damage including water stress [42]. Humic substances are constituent fractions of organic matter and are highly complex and biologically active. These substances include humic acids (HA), fulvic acids (FA), and humin. Humic substances are known to stimulate the root system and plant growth and to mitigate stress damage, including hydric stress. Humic acids have already been reported to increase microbial growth affecting their beneficial effect on plants. Vermicompost application improved the bio-available, slow-releasing nitrogen for the better growth of plants. In addition to nitrogen supply, the vermicompost supplies micronutrients like calcium, magnesium, potassium and other important nutrients needed by the plants for their growth. Organic carbon available in the soil significantly increases the soil fertility and survival of rhizobia [43].

3.5 Yield of soybean during field application studies

Maximum yield of 1.85 ton/hectare was observed from the vermicompost applied plot, 1.69 ton/hectare was observed in the biofertilizer- *Rhizobium* applied plot whereas 1.63 ton/hectare was observed in the FYM applied plot. Nagavallemma *et.al*., [44] reported that vermicompost plays a major role in improving growth and yield of different field crops, vegetables, flowers and fruit crops. The maximum recorded grain yield of 1.82 ton/hectare with the soybean JS variety was reported by Keisham *et.al*., [45]. The maximum yield of Sorghum (*Sorghum bicolor*) with the application of vermicompost was reported by Patil and Sheelavantar [46] and in sunflower (*Helianthus annuus*) maximum yield reported by Devi and Agarwal [47].

CONCLUSION

The application of organic manures like vermicompost, farmyard manure and biofertilizer *Rhizobium* improves soil fertility and ameliorates soil quality by the way of proper utilization of agro-waste is possible. Bio-gold like vermicompost strongly influences the physico-chemical and microbial quality of the soil in a sustainable manner. Soybean is a protein rich crop which supports for human health and also improves the soil fertility by its nodulation and nitrogen fixation efficiency. The present study gives clear insights of organic farming practice by using vermicompost, farmyard manure and *Rhizobium* - a biofertilizer clearly evidenced by its support for the better physicochemical properties and maximum microbial count. More interest is directed towards this approach by many scientists to prove better technology for the farmers concern related to the profitable farming and augmenting the environment through climate smart agricultural practices.

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