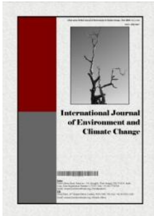

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Effect of Vermicompost Enriched with Biofertilizers, Bioagents and Micronutrients on Growth and Yield of Groundnut (*Arachis hypogaea* L.)

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

Aims: To study the response of groundnut (*Arachis hypogaea* L.) to vermicompost enriched with biofertilizers, bioagents and micronutrients.
Study Design: Field experiment was conducted at Junagadh (Gujarat) with ten treatments comprising of vermicompost enriched with biofertilizers, bioagents and micronutrients *viz*., Absolute Control (T_1), 100% Recommended dose of fertilizers (T_2), Vermicompost 2 t/ha (T_3), Vermicompost 2 t/ha + Biofertilizers (Rhizobium *Bradyrhizobium japonicum* + Phosphate Solubilizing Bacteria *Bacillus subtilis* + Potash Solubilizing Bacteria *Frateuria aurantia* each at 2 L/ha) (T_4), Vermicompost 2 t/ha + *Trichoderma harzianum* 3 kg/ha + *Pseudomonas fluorescens* 3 L/ha (T_5), Vermicompost 2 t/ha + *Beauveria bassiana* 3 kg/ha (T_6), Vermicompost 2 t/ha + Biofertilizers (*Rhizobium* + Phosphate Solubilizing Bacteria + Potash Solubilizing Bacteria each 2 L/ha) + *Trichoderma harzianum* 3 kg/ha + *Pseudomonas fluorescens* 3 L/ha + *Beauveria bassiana* 3 kg/ha (T_7), Micronutrients (Fe + Zn + Cu + Mn) Grade-V at 40 kg/ha (T_8), Vermicompost 2 t/ha + Micronutrients (Fe + Zn + Cu + Mn) Grade-V at 40 kg/ha (T_9) and Vermicompost 2 t/ha + Biofertilizers (*Rhizobium* + Phosphate Solubilizing Bacteria + Potash Solubilizing Bacteria each 2

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L/ha) + *Trichoderma harzianum* 3 kg/ha + *Pseudomonas fluorescens* 3 L/ha + *Beauveria bassiana* 3 kg/ha + Micronutrients (Fe + Zn + Cu + Mn) Grade-V at 40 kg/ha (T_{10}) in Randomized Block Design with three replications.
Place and Duration of the Study: Instructional Farm, Department of Agronomy, College of Agriculture, Junagadh Agricultural University, Junagadh (Gujarat) during *kharif* seasons of 2019 and 2020.
Methodology: Five plants were selected randomly from each net experimental plot and tagged. Growth parameters *viz.,* plant height, number of branches, SPAD meter reading and number of root nodules, and yield attributes *viz.,* number of mature pods per plant and pods weight per plant were recorded from that tagged plants and their average was considered for final record. Pod yield and haulm yield were recorded from net plot size of each experiment plot and converted in to hectare base. Shelling percentage was counted on the basis of 150 g pod sample taken randomly from net plot produce.
Results: The results indicated that the highest plant height (35.64 cm), number of branches per plant (8.11), number of root nodules per plant (154.5) at 45 days after sowing (DAS), dry weight of root nodules per plant at 45 DAS (0.982 g), Soil Plant Analysis Development (SPAD) meter reading at 45 DAS (39.09), number of mature pods per plant (18.40), pod weight per plant (15.37 g), 100-kernel weight (44.08 g) and shelling percentage (73.16%) with the highest pod yield (2.305 t/ha) and haulm yield (3.889 t/ha) were achieved by application of Vermicompost 2 t/ha + Biofertilizers (*Rhizobium* + Phosphate Solubilizing Bacteria + Potash Solubilizing Bacteria each 2 L/ha) + *Trichoderma harzianum* 3 kg/ha + *Pseudomonas fluorescens* 3 L/ha + *Beauveria bassiana* 3 kg/ha + Micronutrients (Fe + Zn + Cu + Mn) Grade-V at 40 kg/ha, which is considered the more effective application among all treatments improves growth, pod and haulm yield of groundnut under clay soil conditions.

Keywords: Groundnut; enriched vermicompost; biofertilizers; bioagents; micronutrients.

1. INTRODUCTION

Groundnut (*Arachis hypogaea* L.) is an annual legume, which is also known as peanut, earthnut, monkey nut and goobers. Groundnut is known as poor man's almond. It is the 13^{th} most important food crop and fourth most important oilseed crop of the world. Groundnut seed contain about 50% edible oil. The remaining 50% of the seed has high quality protein (21.4 to 36.4%), carbohydrates (6.0 to 24.9%), vitamin E, niacin, falacin, calcium, phosphorus, magnesium, zinc, iron, riboflavin, thiamine and potassium [1]. The groundnut oil is generally used in the preparation of *vanaspati ghee*, soap, cosmetics and cold creams besides as cooking medium. These multiple uses of groundnut make it an excellent cash crop for domestic markets as well as for foreign trade in several developing and developed countries. Kernels are also being used as processed foods like sweets and dry powdered. Groundnut haulm and oil cake are used as either cattle feed or organic manure. The shells of groundnut are also utilized as fuel in boilers and as filler material in many organic and biological products like activated charcoal, cork substitutes and hard boards. Being a legume, groundnut plant symbiotically fixes atmospheric nitrogen and improves the soil fertility status. Groundnut is one of the most popular and universal crops cultivated in more than 120 countries. It is grown in about 24 M ha area with a total production of 35 M tonnes under different agro-climatic zones between 40°S and 40°N [2]. In India, it is cultivated on area of 1.16 M ha with production of 6.5 MM tonnes and productivity 5.6 Metric tons/ha [3].

There is a great awareness worldwide in recent years regarding the excess use of inorganic fertilizers and other chemicals that lead to environmental pollution and pest outbreaks. Continuous use of inorganic fertilizers plays a vital role in deteriorating the soil health. Rising costs of commercial fertilizers and increasing demand to produce more organic food will continue to increase the value of manure and organic waste material as a nutrient source for crops and to regenerate degraded soils. Use of organic manure is the best remedy for maintaining soil quality as well as productivity and replacing mineral fertilizers. Apart from the nutritional value, the beneficial microorganisms, especially PGPR (Plant Growth Promoting Rhizobacteria), are grown in the simple, cheap media and they are mixed with the appropriate carriers to produce biofertilizers. Such PGPRs also fix nitrogen legume crops like red gram, blackgram, groundnut, cowpea, and soybean, which help in 50-300 kg nitrogen fixation from soil and helps in saving about 25-100 kg chemical nitrogen *i.e.* 55-220 kg urea per hectare.

Indian soils have poor to medium status in available phosphorus. Phosphorus is immobile in soil systems and hardly 15 to 20% of the applied phosphorus is utilized by a crop to which it is applied. While the rest remains in a fixed state in soil being influenced by various physico-chemical and biological properties of the soil [4]. Several bacteria belonging to genera *Pseudomonas* and *Bacillus* have the ability to solubilize inorganic phosphorus insoluble sources. Inoculation of seed with phosphate solubilizing bacteria (PSB) increases crop growth, nutrient availability, uptake and crop yield [5].

Potassium solubilizing bacteria play vital role in making available insoluble forms of potassium by mineralization. In Indian soil, the soluble K form are present in approximately 2% and insoluble are present in range of 98% in form of minerals like biotite, feldspar, mica, muscovite, vermiculite [6]. Potassium solubilizing bacteria solubilizes potassium from insoluble forms like mica, feldspar and others by producing organic acids, siderophores and also capsular polysaccharides. Potassium uptake of plants can be increased by using potassium solubilizers as bio-inoculants further increasing the crop production.

Beauveria bassiana is becoming increasingly popular to protect crop yields from losses due to pest infestation. *B. bassiana* is a well-known entomopathogenic fungus that can parasitize more than 700 different kinds of insects [7]. Isolates of *B. bassiana* can antagonize a variety of soil and foliar plants pathogens [8] while they are in symbiosis with many plant species. However, knowledge about the impact of *B. bassiana* on soil microbial flora and enzyme activities after application is largely lacking.

Trichoderma spp. are the most frequently isolate soil fungi and present in plant root ecosystems. These fungi are opportunistic, avirulent plant symbionts and functions as parasites and antagonists of many phytopathogenic fungi, thus protecting plants from diseases. So far, these are among the most studied fungal bio-control agents and commercially marketed as biopesticides, biofertilizers and soil amendments [9]. These organic materials help to improve physical, chemical and biological properties of soils and thereby help to increase fertility and productivity.

The traditional technology of vermicompost, if improved in terms of biological and nutritional enrichment, may to reduce the nutrient depletion trends and diseases/pest problem to a greater extent. Vermicompost is the best organic carrier for microbial cultures, hence it can be enriched by N fixing microorganisms like *Rhizobium*, *Azotobacter*, *Azospirillum* etc.; phosphate solubilizing microorganisms, namely, *Aspergillus awamori*, *Pseudomonas striata* and *Bacillus megaterium*; K solubilizing/mobilizing microorganisms, cellulolytic/waste decomposing microorganisms, and different microbial bioagents like *Trichoderma, Pseudomonas fluorescens, Beauveria, Metarhizium*, *Verticillium etc*. and micronutrients to prepare a single product and to increase the manurial and biological value of the vermicompost. Looking to the above facts, this experiment was aimed to evaluate vermicompost enriched with microbial consortia and micronutrients by studying its effect on the growth and yield of kharif groundnut under clay soil conditions.

2. MATERIALS AND METHODS

The study was conducted at Instructional Farm, Department of Agronomy, College of Agriculture, Junagadh Agricultural University, Junagadh during *kharif* seasons of 2019 and 2020. Geographically, Junagadh is located at 21.5° N latitude and 70.5° E longitude with an altitude of 60 m above the mean sea level on the western side on the foothill of mountain ‘Girnar’ under South Saurashtra Agro-climatic Zone of Gujarat state and enjoys a typically subtropical climate characterized by fairly cold and dry winter, hot and dry summer and warm and moderately humid monsoon. The soil of the experimental plot was clayey in texture and slightly alkaline in reaction. The soil was low in available nitrogen (225 and 230 kg/ha), medium in available phosphorus (30.25 and 33.50 kg/ha), medium in available potassium (280 and 288 kg/ha), low in sulphur (8.94 and 9.80 mg/kg), low in iron (3.80 and 4.02 mg/kg), medium in manganese (6.50 and 7.15 mg/kg), low in zinc (0.46 and 0.48 mg/kg) and high in copper (1.26 and 1.30 mg/kg) in 2019 and 2020, respectively. In the study, crop is groundnut “Gujarat Junagadh Groundnut 22” variety to carry out the present investigation. Ten treatments comprising of vermicompost enriched with biofertilizers, bioagents and micronutrients *viz*., Absolute Control (T_1), 100% recommended dose of fertilizers (RDF) (T_2), Vermicompost 2 t/ha (T_3), Vermicompost 2 t/ha + Biofertilizers (*Rhizobium* + PSB + KSB each 2 L/ha) (T_4), Vermicompost 2 t/ha + *Trichoderma harzianum* 3 kg/ha + *Pseudomonas fluorescens* 3 L/ha (T_5), Vermicompost 2 t/ha + *Beauveria bassiana* 3 kg/ha (T_6), Vermicompost 2 t/ha + Biofertilizers (*Rhizobium* + PSB + KSB each 2 L/ha) + *Trichoderma harzianum* 3 kg/ha + *Pseudomonas fluorescens* 3 L/ha + *Beauveria bassiana* 3 kg/ha (T_7), Micronutrients (Fe + Zn + Cu + Mn) Grade-V at 40 kg/ha (T_8), Vermicompost 2 t/ha + Micronutrients (Fe + Zn + Cu + Mn) Grade-V at 40 kg/ha (T_9) and Vermicompost 2 t/ha + Biofertilizers (*Rhizobium* + PSB + KSB each 2 L/ha) + *Trichoderma harzianum* 3 kg/ha + *Pseudomonas fluorescens* 3 L/ha + *Beauveria bassiana* 3 kg/ha + Micronutrients (Fe + Zn + Cu + Mn) Grade-V at 40 kg/ha (T_{10}) were tested in randomised block design with three replications. The enrichment of vermicompost as per treatments was done 10 days before application to the field and kept in shade with maintaining 20-25% moisture. The groundnut cv. GJG 22 was sown at onset of monsoon with a spacing of 60 cm x 10 cm with standard package of practices and harvest at 118 days after sowing. Five plants were selected randomly from each net experimental plot and tagged. Growth parameters *viz.,* plant height, number of branches, SPAD meter reading, number of root nodules, and yield attributes *viz.,* number of mature pods per plant and pod weight per plant were recorded from that tagged plants and their average was considered for final record. For the 100-kernel weight, random sample were taken and shelling percentage was counted on the basis of 150 g pod sample taken randomly from net plot. Pod yield and haulm yield were recorded from net plot size of each experiment plot and converted in to hectare base. The data were subjected to statistical analysis by adopting appropriate analysis of variance [10]. Wherever the F values found significant at 5 per cent level of probability, the critical difference (CD) values were computed for making comparison among the treatment means.

3. RESULTS AND DISCUSSION

3.1 Effect of Enriched Vermicompost on Vegetative Growth and Flowering

Application of vermicompost 2 t/ha enriched with biofertilizers (*Rhizobium* + PSB + KSB each 2 L/ha), bioagents (*Trichoderma harzianum* 3 kg/ha + *Pseudomonas fluorescens* 3 L/ha + *Beauveria bassiana* 3 kg/ha) and micronutrients [(Fe + Zn + Cu + Mn) Grade-V at 40 kg/ha] (T_{10}) registered significantly the highest plant height (35.64 cm), most number of branches per plant (8.11), maximum number of root nodules per plant (154.48) at 45 days after sowing (DAS), highest dry weight of root nodules per plant at 45 DAS (0.982 g) and the highest SPAD meter reading at 45 DAS (39.09) (Table 1), but plant height, number of branches per plant and dry weight of root nodules per plant remained statistically at par with Vermicompost 2 t/ha + Biofertilizers (*Rhizobium* + PSB + KSB each 2 L/ha) + *Trichoderma harzianum* 3 kg/ha + *Pseudomonas fluorescens* 3 L/ha + *Beauveria bassiana* 3 kg/ha (T_7) and number of root nodules, days to 50% flowering and SPAD meter reading remained statistically at par with 100% RDF (T_2) and Vermicompost 2 t/ha + Biofertilizers (*Rhizobium* + PSB + KSB each 2 L/ha (T_4). Same results were noticed by Verma et al. [11] and Ravikumar et al. [12]. However, the lowest plant height (27.22 cm), lowest number of branches per plant (6.35), minimum number of root nodules per plant at 45 DAS (118.14), lowest dry weight of root nodules per plant at 45 DA (0.435 g), latest flowering (48.82 days) and Soil Plant Analysis Development meter reading at 45 DAS (31.63) were noticed under the absolute control (T_1). Improvement in growth parameters with enriched vermicompost which might be due to adequate supply of N, P and K during the plant growth period through vermicompost enriched with the *Rhizobium*, PSB, KSB and bioagents like *Trichoderma harzianum, Pseudomonas fluorescens*, *Beauveria bassiana* improved physical, chemical and biological properties of soil with enriched vermicompost. These might have increased the availability of nutrients in the rhizosphere. Nitrogen being essential constituent of various amino acids and proteins as well as structural constituent of cell, it influences different physiological processes such as cell division and elongation. Phosphorus plays an important role in conversion of solar energy into chemical energy and it has also beneficial effect on root proliferation that increases the absorption of plant nutrients and moisture from soil. Potassium triggers activation of enzymes and is essential for production of adenosine triphosphate (ATP) and plays a major role in regulation of water, the opening-closing of stomata and therefore regulates CO_2 uptake. Symbiotic N fixation along with solubilization of P and K with microbial enrichment in vermicompost might have increased nutrients availability, which reflected in triggered growth of the crop. These results confirm the findings of Manivannan and Thilagavathi [13], Kagne et al. [14], Manivannan and Deniel [15], Zalate and Padmani [16], Patel [17], Rehman and Dar [18], Kamdi et al. [19] and Immanuel et al. [20].

3.2 Effect of Enriched Vermicompost on Productivity

The experimental result revealed the significant effect of different treatments on yield attributes and yield (Table 2). Significantly maximum number of mature pods per plant (18.40), pod weight per plant (15.37 g), 100-kernel weight (44.08 g), shelling percentage (73.16%), pod yield (2.305 t/ha) and haulm yield (3.889 t/ha) were recorded with the application of Vermicompost 2 t/ha + Biofertilizers (*Rhizobium* + PSB + KSB each 2 L/ha) + *Trichoderma harzianum* 3 kg/ha + *Pseudomonas fluorescens* 3 L/ha + *Beauveria bassiana* 3 kg/ha + Micronutrients (Fe + Zn + Cu + Mn) Grade-V at 40 kg/ha (T_{10}), however number of mature pods per plant, pod weight per plant and 100-kernel weight remained statistically at par with 100% recommended dose of fertilizer (T_2) and Vermicompost 2 t/ha + Biofertilizers (*Rhizobium* + PSB + KSB each 2 L/ha) (T_4) in most of the cases. But pod yield, haulm yield and shelling percentage were noticed statistically at par with

Table 1. Effect of enriched vermicompost on growth attributes of groundnut (Pooled over two years)

Treatment	Plant height (cm)	Number of branches per plant	Number of root nodules at 45 DAS	Dry weight of root nodule per plant at 45 DAS (g)	Days to 50% flowering	SPAD meter reading at 45 DAS
T_1	27.22	6.35	118.1	0.435	48.82	31.63
T_2	34.98	7.06	149.9	0.742	40.32	38.36
T_3	30.44	7.01	121.6	0.560	45.78	32.05
T_4	33.00	7.44	146.8	0.898	41.27	37.98
T_5	28.52	6.79	131.1	0.628	45.29	32.83
T_6	30.36	6.72	134.3	0.818	43.76	37.06
T_7	34.84	7.75	132.3	0.928	43.50	33.86
T_8	30.33	7.06	129.8	0.608	44.94	32.45
T_9	29.92	7.09	135.8	0.823	41.82	37.71
T_{10}	35.64	8.11	154.5	0.982	39.42	39.09
S.Em.±	1.12	0.22	5.0	0.025	1.24	1.22
CD (P=0.05)	3.22	0.63	14.3	0.071	3.56	3.50

Table 2. Effect of enriched vermicompost on yield attributes and yield of groundnut (Pooled over two years)

Treatment	Number of mature pods per plant	Pod weight per plant (g)	100-kernel weight (g)	Shelling (%)	Pod yield (t/ha)	Haulm yield (t/ha)
T_1	13.43	10.42	34.08	61.15	1.127	1.875
T_2	18.09	14.42	41.32	62.84	1.892	3.247
T_3	13.90	11.33	36.57	64.17	1.590	2.726
T_4	15.21	14.05	42.01	67.93	1.832	3.125
T_5	13.97	12.48	39.60	63.85	1.696	2.934
T_6	14.98	13.07	40.50	67.57	1.771	2.986
T_7	15.24	12.81	40.80	71.92	2.116	3.646
T_8	14.14	11.62	38.49	66.20	1.320	2.292
T_9	15.20	13.50	40.88	68.36	2.005	3.385
T_{10}	18.40	15.37	44.08	73.16	2.305	3.889
S.Em.±	0.65	0.57	1.23	1.41	0.094	0.137
CD (P=0.05)	1.87	1.64	3.52	4.04	0.270	0.393

the treatment of Vermicompost 2 t/ha + Biofertilizers (*Rhizobium* + PSB + KSB each 2 L/ha) +*Trichoderma harzianum* 3 kg/ha + *Pseudomonas fluorescens* 3 L/ha + *Beauveria bassiana* 3 kg/ha (T_7). Same results were observed by Zalate and Padmani [16], Manivannan and Daniel [15] and Pradeepa et al. [21], Verma et al. [9]. It could ascribe to beneficial and combined effects of enrichment of vermicompost with biofertilizers, bioagents and micronutrients, which can enhance nutrient transformations in soil by improving physical, chemical and biological properties of soil. Whereas, the lowest values of yield and yield attributes in groundnut were recorded under the absolute control (T_1). These findings are in agreement with those of Govindan and Thirumurugan [22], Manivannan and Thilagavathi [13], Kagne et al. [14], Randhe et al. [23], Shaikh et al. [24], Mehta [25], Chavan et al. [26], Kamdi et al. [19], Kumar et al. [27], Verma et al. [11], Ravikumar et al. [12] and Reddy et al. [28].

4. CONCLUSION

On the basis of the results obtained from the present two-year field experimentation, it seems quite logical to conclude that higher production from *kharif* groundnut can be secured by application of vermicompost 2 t/ha enriched with biofertilizers (*Rhizobium* + PSB + KSB each 2 L/ha), bioagents (*Trichoderma harzianum* 3 kg/ha + *Pseudomonas fluorescens* 3 L/ha + *Beauveria bassiana* 3 kg/ha) and micronutrients [(Fe + Zn + Cu + Mn) Grade-V at 40 kg/ha] on calcareous clayey soil of South Saurashtra Agro-climatic Zone.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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