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RESPONSE OF GROUNDNUT AND FABA BEAN TO ORGANIC CHEMICAL AND MICROBIAL FERTILIZERS IN THREE TYPES OF SOILS IN SUDAN

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Abstract

Purpose: The aim of this study was to investigate the effect of organic chemical and microbial fertilizers on the growth of groundnut and faba bean grown in three types of soils.

Design/methodology/approach: Two pot experiments were conducted at the nursery of the Faculty of Agriculture, University of Khartoum during the summer of 2009 and winter 2009–2010. The treatments were arranged in a completely randomized design with three replications. Chicken manure, manufactured organic fertilizers (Elkhaseeb, Elkhairat and Abu floos), Effective Microorganisms (EM), *Rhizobium* and urea were used in three soil types (Shambat, Elrawakeeb and Gerif). Chicken manure and manufactured organic fertilizers were applied at the rate equivalent to 40 Kg N/ha and urea was applied at the rate of 40 Kg N/ha. Data were collected on the number of nodules, plant height, dry weight of shoots and roots at ten weeks after sowing. The nitrogen, phosphorus and potassium content of shoots were determined at ten weeks after sowing.

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Findings: The results showed that urea and organic fertilizers, especially Elkhaseeb, significantly increased most of the measured parameters for both crops compared to the unfertilized control. *Rhizobium* inoculation significantly increased dry weight of shoots and nodules, number of groundnut and dry weights of shoots, roots, plant height and potassium content of faba bean. Effective microorganisms showed no significant improvements in most of the measured parameters for both crops compared to the untreated control. The results indicated significant differences between soils, with Shambat soil being the best, followed by Gerif and Elrawakeeb soils. It is suggested that locally produced organic fertilizers should be encouraged and standards for their quality should be developed. Very strict measures and standards should be imposed as well as careful inspection for all imported microbial fertilizers. Originality/value: This research was carried out by three researchers from two institutions concerned with organic production of legumes in Sudan. The paper emphasizes the efficiency of new commercial organic and microbial fertilizers to conventionally used fertilizers in Sudan on faba bean and groundnut grown on three types of soils.

Keywords: *Organic fertilizer, Microbial fertilizer, Sudanese soil, Legumes*

Paper type: Research paper

INTRODUCTION

Low soil fertility is considered one of the most important constraints on improved agricultural production (Ayoub, 1999). Fertilizers are used to improve fertility and are indispensable for sustained food production, but excessive use of mineral fertilizers has aroused environmental concerns. Organic fertilizers coming from fermented and decomposed organic materials are generally nutritious and safe. Microbial fertilizers are apparently environment friendly, low cost and non-bulky agricultural inputs which play a significant role in plant nutrition as a supplementary and complementary factor to mineral nutrition (Mahajan *et al.*, 2008). Therefore fertilizer and plant nutrition research should establish a workable relation between environment preservation and fertilizers (Fageria *et al.*, 2008).

Legumes are an important source of protein for humans and animals. They provide nutritionally rich crop residues for animal feed and play a key role in maintaining the productivity of soil. Legumes also play a unique role due to their ability of fixing atmospheric nitrogen (Elsheikh, 2011). In Sudan, faba bean (*Vicia faba* L.) and groundnut (*Arachis* *hypogaea* L.) are mainly grown for human consumption, and groundnut is one of the most important oil crops, whereas faba bean is one of the most important food crops.

The objectives of this work were to compare the effects of microbial fertilizers (EM), different new commercial organic amendments "Elkhaseeb", "Elkhairat", and "Abu floos" on groundnuts and faba bean grown on Shambat, Elrawakeeb and Gerif soils and to compare the efficiency of new commercial organic and microbial fertilizers to conventionally used fertilizers, namely chicken manure, *Rhizobium* and urea.

MATERIALS AND METHODS MATERIALS

Seeds

Groundnut seeds of the variety "Al Geziera" were obtained from Elhudeiba Research Station, Sudan, and faba bean seeds of the variety "Agabat" were obtained from the local market, Khartoum, Sudan.

Fertilizers

Urea, four organic fertilizers and two microbial fertilizers were used in this study. Urea (80 Kg N/ha) was applied two weeks after sowing. Two *Bradyrhizobium* strains were obtained from the Department of Biofertilization, Environment and Natural Resources Research Institute, National Centre for Research. *Bradyrhizobium* was added in a liquid form (5 ml per plant) two weeks after sowing. *Bradyrhizobium* strain TAL 169 was used for groundnut and *Bradyrhizobium* TAL1399 for faba bean. Microbial fertilizer, EM, is a liquid microbial consortium based on diluted molasses. It contains yeast (*Saccharomyces cerevisiae*), lactic acid bacteria (*Rhodopseudomonas palustris)*, and photosynthetic bacteria (*Rhodobacter sphaeroides*). It was obtained from Elmurug Company, Khartoum, at Elselate scheme. Diluted EM (5 ml to 1 litre water) was applied two weeks after sowing and then every two weeks until 8 weeks after sowing.

Chicken manure (Table 1) was collected from the poultry farm, Faculty of Animal Production, University of Khartoum, Shambat, Sudan. Elkhaseeb composted organic fertilizer was obtained from Elkaseeb factory at Elbagir. It was prepared as a mixture of sheep manure, farmyard manure and chicken manure in 1:2:1 ratio. Elkhairat, a composted organic fertilizer, was obtained from Elkhairat factory at Elselate scheme. It consists of cow manure, chicken manure and agricultural residues.

Abu floos, a composted organic fertilizer, was obtained from the local market. It is a mixture of chicken manure and cattle manure thermally treated and incompletely fermented. All organic fertilizers were applied at the rate equivalent to 80 Kg N/ha and were added two weeks before sowing, and the soil was irrigated twice before sowing.

The soils

Three types of soils were used in this study, namely (i) Shambat soil from the field of the Faculty of Agriculture, University of Khartoum, Shambat, Sudan, (ii) Elrawakeeb soil from Elrawakeeb Research Station, National, Centre for Research, Sudan, and (iii) Gerif soil from the River Nile bank. The soils from different sites were collected from a depth of 0-30 cm.

Soils were cleaned free of debris, lumps were broken with a wooden stick, and the soils were then mixed thoroughly and analyzed. Particle size distribution indicated that these soils were clay, sandy loam and silt clay loam. The pH varied from slightly alkaline (7.54) to neutral (7.00 and 7.28), low (NPK) values, total nitrogen (0.07%, 0.01% and 0.11%), total phosphorus (0.41%, 0.34% and 0.43%) and soluble potassium (0.38, 0.10 and 0.13 mmol/l), non-saline EC (1.33, 0.18 and 0.58 dS/m) for Shambat, Elrawakeeb and Gerif soils, respectively.

Pot experiments

Two pot experiments were carried out at the Department of Horticulture, Faculty of Agriculture, University of Khartoum, Shambat. Five kg of soil was placed in plastic bags (30×40cm). Four small holes were made per bag for drainage of excess water to avoid water logging. Groundnut was sown on the 13thof August 2009, and faba bean was sown on the 9th of December 2009. Three seeds were sown in each bag and irrigated with tap water at two day intervals. Plant samples were taken at ten weeks from sowing. Seven fertilizers treatments, namely urea, EM, Elkhaseeb, Elkhairat, Abu floos, *Rhizobium* or chicken manure were used in addition to the control. Each experiment was arranged in a completely randomized design (CRD) with three replications.

Growth and yield parameters

The number of nodules was determined at six, eight and ten weeks after sowing, plant height was determined at ten weeks after sowing. After oven drying at 70°C for 72 hours, root and shoot dry weights were determined at ten weeks after sowing.

Plant analysis

After oven drying at 70°C for 72 hours, plants were ground to pass through a 0.50 mm sieve. Shoot nitrogen, phosphorus and potassium content were determined according to AOAC methods (1990) at ten weeks after sowing.

Statistical analysis

Data collected from the experiments were analyzed as a factorial complete randomized design. Analysis of variance (ANOVA) was performed according to the method described by Gomez and Gomez (1984). Means were separated by using Duncan's Multiple Range Test (DMRT).

RESULTS

Nodule number per plant

The fertilizer treatments significantly ($p \leq 0.05$) affected the nodule numbers in groundnut at eight and ten weeks from sowing, except urea and EM, compared to the control treatment (Table 2). Elrawakeeb soil showed the highest significant nodule number compared to other soil types. Elkhaseeb fertilizer applied to Elrawakeeb soil showed the highest nodule number at eight and ten weeks after sowing. The nodule number for faba bean was not significantly affected by the fertilizers and the soil types after six, eight and ten weeks from sowing (data not shown).

Plant height

The plant height of groundnut was neither significantly affected by the fertilizers nor by the soil types at ten weeks from sowing (Table 3). EM and Elkahirat significantly ($p \leq 0.05$) affected the plant height of faba bean after ten weeks (Table 4). EM, Elkahirat, and *Rhizobium* significantly increased the plant height of faba bean when applied to Shambat soil,

Table 1. Chemical composition of organic fertilizers used in this study

Mg (%)	Ca (%)	P (%)	K mmol/l	Na mmol/l	OM (%)	O.C (%)	N (%)	Fertilizers
2.53	8.30	0.70	6.84	5.34	49.2	28.6	2.80	Chicken manure
3.01	5.00	0.70	6.99	4.44	55.9	32.5	1.41	Elkhaseeb
4.50	5.82	0.30	4.35	1.98	20.1	11.7	1.02	Elkhairat
1.51	8.30	0.28	7.11	1.80	17.9	10.4	1.03	Abu floos

Table 2. Effects of organic, chemical and biological fertilizers on nodule number per plant of groundnut grown in three types of soils

	Fertilizers								
Soils	**Control**	**Urea**	**EM**	**Elkhaseeb**	**Elkhairat**	**Abu floos**	**CM**	***Rhizobium***	Soil means
					6 weeks				
Shambat	18.6bcd	3.0d	4.0d	8.0d	1.6d	5.0d	1.6d	60.3a	12.7B
Rawakeeb	7.3d	33.3abcd	5.3d	47.6abc	65.6a	54.6ab	47.0abc	33.0abcd	37.2A
Gerif	0.0d	4.0d	10.0d	8.6d	12.3cd	3.0d	6.6d	7.0d	6.4B
Mean	8.6A	13.4A	6.4A	21.4A	26.5A	20.8A	18.4A	33.4A	
					8 weeks				
Shambat	13.0fg	22.0fg	38.6defg	4.3g	21.6fg	28.0fg	104.0bcde	91.0bcdef	40.3B
Rawakeeb	1.6g	72.3cdefg	39.6defg	224.6a	108.6bcd	121.0bc	154.3b	56.0cdaefg	99.7A
Gerif	4.6g	29.3efg	24.6fg	42.3defg	21.3fg	4.0g	17.0fg	21.6fg	20.6B
Mean	6.0D	41.0CD	34.0CD	97.0A	50.5C	51.0C	91.0AB	56.0BC	
					10 weeks				
Shambat	13.0ef	38.6def	34.0def	6.3f	164.3bc	134.3bcd	67.3cdef	106.0bcdef	70.0B
Rawakeeb	34.3def	123.3bcd	77.3cdef	261.0a	90.3cdef	195.0ab	110.0bcde	106.6bcdef	124.0A
Gerif	50.3def	18.0ef	33.3def	74.0cdef	49.0def	64.3cdef	109.6bcdef	71.3cdef	58.0B
Mean	32.5..0C	60.0BC	48.0C	113.0AB	101.2.AB	131.0A	95.0AB	94.0AB	

Means followed by the same letter(s) are not significantly different at p≤ (0.05) according to Duncan's Multiple Range Test.

Table 3. Effects of organic, chemical and biological fertilizers on plant height (cm/plant), shoot dry weight (g/plant) and root dry weight (g/plant) of groundnuts grown in three types of soils at ten weeks after sowing

	Fertilizers								
Soils	Control	Urea	EM	Elkhaseeb	Elkhairat	Abu floos	CM	*Rhizobium*	Soil means
				Plant height					
Shambat	21.6a	21.3a	21.5a	25.9a	23.4a	19.7a	22.1a	21.2a	22.1A
Rawakeeb	19.8a	18.5a	17.2a	21.6a	26.7a	16.6a	18.8a	22.1a	20.1A
Gerif	24.4a	26.3a	20.1a	21.0a	21.4a	23.4a	23.1a	21.3a	22.6A
Mean	21.9A	22.0A	19.6A	22.8A	23.8A	19.9A	21.3A	21.5A	
				Shoot dry weight					
Shambat	6.7bcde	11.4abcd	7.0abcde	8.8abcde	13.9ab	7.7abcd	3.3e	7.9abcde	8.8A
Rawakeeb	5.5cde	4.7cde	3.8de	6.9abcde	12.4abc	14.6a	5.4cde	3.4e	7.1A
Gerif	6.7bcde	8.7abcde	6.1bcde	5.4cde	5.2cde	7.5abcde	9.1abcd	6.5bcde	6.9A
Mean	6.3AB	8.3AB	5.6B	7.0AB	10.5A	9.9AB	7.3AB	5.6B	
				Root dry weight					
Shambat	0.32bc	0.47bc	0.35bc	0.51bc	0.60b	0.50bc	0.31bc	0.39bc	0.43A
Rawakeeb	0.33bc	0.54b	0.18c	1.07a	0.35bc	0.51bc	0.28bc	0.39bc	0.46A
Gerif	0.35bc	0.40bc	0.35bc	0.35bc	0.36bc	0.29bc	0.46bc	0.43bc	0.37A
Mean	0.33B	0.47AB	0.30B	0.64A	0.44B	0.43B	0.35B	0.40B	

Means followed by the same letter(s) are not significantly different at p≤ (0.05) according to Duncan's Multiple Range Test.

Table 4. Effects of organic, chemical and biological fertilizers on plant height (cm/plant), shoot dry weight (g/plant) and root dry weight (g/plant) of faba bean grown in three types of soils at ten weeks after sowing.

	Fertilizers								
Soils	Control	Urea	EM	Elkhaseeb	Elkhairat	Abu floos	CM	*Rhizobium*	Soil means
				Plant height					
Shambat	24.6fg	25.2fg	36.0abcde	23.4g	39.1abc	30.3cdefg	25.1fg	34.5abcde	29.0B
Rawakeeb	37.4abcd	31.2cdefg	36.8abcde	35.9abcde	40.3ab	29.7defg	37.9abcd	38.6abcd	36.0A
Gerif	28.5efg	38.1abcd	41.3a	37.9abcd	32.8abcdef	41.2a	35.2abcde	31.3bcdefg	35.0A
Mean	30.1C	31.5C	38.0A	32.4C	37.4AB	33.7ABC	32.7BC	34.8ABC	
				Shoot dry weight					
Shambat	0.79bcdef	1.22abcd	1.50ab	1.2abcde	0.56def	1.56ab	0.43ef	1.61a	1.11A
Rawakeeb	1.05abcde	0.93abcde	0.88abcde	0.99abcde	1.34abcd	0.62cdef	0.11f	1.57ab	1.06A
Gerif	0.95abcde	0.96abcde	1.55ab	1.3abcd	1.10abcde	1.27abcd	1.19abcde	1.38abc	1.21A
Mean	0.93B	1.03B	1.31AB	1.16AB	1.00B	1.15AB	0.91B	1.52A	
				Root dry weight					
Shambat	0.24a	0.92a	0.75a	0.71a	0.26a	0.43a	0.25a	0.27a	0.48C
Rawakeeb	0.69a	1.09a	0.90a	1.67a	2.18a	1.08a	0.70a	0.63a	1.11B
Gerif	1.14a	1.64a	2.51a	1.42a	1.94a	2.48a	2.65a	0.97a	1.84A
Mean	0.69AB	1.21A	1.38A	1.26A	1.46A	1.33A	1.20A	0.63AB	

Means followed by the same letter(s) are not significantly different at p≤ (0.05) according to Duncan's Multiple Range Test.

while Abu floos, Elkhaseeb, urea and EM showed a significant effect on Gerif soil. Elrawakeeb and Gerif soils showed significantly higher plant height compared to Shambat soil at ten weeks after sowing.

Shoot dry weight

Elkhairat significantly ($p\leq0.05$) affected the shoot dry weight of groundnut (Table 3). There were no significant differences between soil types. Abu floos applied to Elrawakeeb soil significantly ($p\leq0.05$) increased the shoot dry weight of groundnut. Shambat soil showed the highest shoot dry weight compared to other soils. *Rhizobium* inoculation significantly increased the shoot dry weight compared to control at ten weeks after sowing. There were no significant differences between soil types, however significant differences were observed in the interaction between *Rhizobium* and Shambat soil (Table 4).

Root dry weight

Elkhasseb significantly increased the root dry weight of groundnut compared to control and other fertilizers at ten weeks after sowing. Elkhasseb applied to Elrawakeeb soil significantly increased the root dry weight of groundnut compared to control. Significant differences between soil types were not observed (Table 3). The fertilizers significantly ($p\leq0.05$) affected the root dry weight of faba bean at ten weeks after sowing except *Rhizobium* inoculation (Table 4). Elrawakeeb and Gerif soils showed the higher root dry weight compared to Shambat soil at ten weeks after sowing.

Nitrogen, phosphorus and potassium contents in shoot

Elkhaseeband *Rhizobium* significantly ($p\leq0.05$) increased the nitrogen content of groundnut compared to the control (Table 5). There were no significant differences in shoot nitrogen content between soil types. The interaction between Elrawakeeb soil and *Rhizobium* gave the highest shoot nitrogen content. Fertilization treatments had no significant effect on the shoot phosphorus content of groundnut compared to the untreated control (Table 5). Shambat soil showed significant increment in shoot phosphorus content compared to Elrawakeeb and Gerif soils. Neither the fertilizer treatments nor the soil types significantly ($p\leq0.05$) affected the shoot potassium content of groundnut (Table 5). The interaction between Elrawakeeb soil and CM showed the highest significant effect on shoot potassium content. All fertilization treatments had no significant ($p\leq0.05$) effect on nitrogen content of faba bean (Table 6). Shambat and

Table 5. Effects of organic, chemical and biological fertilizers on nitrogen, phosphorus, and potassium contents (%) plant of groundnut grown in three types of soils at ten weeks after sowing

	Fertilizers								
Soils	**Control**	**Urea**	**EM**	**Elkhaseeb**	**Elkhairatt**	**Abu floos**	**CM**	***Rhizobium***	**Soil means**
					Nitrogen				
Shambat	1.19gh	2.40def	1.33fgh	3.73ab	1.35fgh	4.13a	2.17efg	4.01ab	2.53A
Rawakeeb	2.45cdef	2.80bcde	2.12efg	3.79ab	3.71ab	3.64abc	3.71ab	4.20a	3.30A
Gerif	3.75ab	3.29abcde	0.93h	4.06a	3.64abc	2.98acde	3.52abcd	2.96abcde	3.14A
Mean	2.46BC	2.83AB	1.46C	3.86A	2.90AB	3.58AB	3.13AB	3.72A	
					Phosphorus				
Shambat	0.31a	0.32a	0.21abcdef	0.25abcd	0.18abcdef	0.24abcdef	0.21abcdef	0.14bcdef	0.23A
Rawakeeb	0.13cdef	0.13cdef	0.28abc	0.21abcdef	0.30ab	0.10def	0.12cdef	0.13cdef	0.17B
Gerif	0.07f	0.12cdef	0.20abcdef	0.08ef	0.18abcdef	0.18abcdef	0.20abcdef	0.23abcdef	0.16B
Mean	0.17A	0.19A	0.23A	0.18A	0.22A	0.17A	0.17A	0.17A	
					Potassium				
Shambat	0.72cdefg	0.99abc	0.80bcde	0.45fg	0.65cdefg	0.72cdefg	0.70cdefg	1.11ab	0.77A
Rawakeeb	0.69cdefg	0.52efg	0.84bcde	0.74cdefg	0.94abcd	0.43g	1.19a	0.73cdefg	0.76A
Gerif	0.68cdefg	0.79bcdef	0.71cdefg	0.87bcd	0.51efg	0.60defg	0.64defg	0.65cdefg	0.68A
Mean	0.70A	0.76A	0.78A	0.69A	0.70A	0.58A	0.84A	0.83A	

Means followed by the same letter(s) are not significantly different at p≤ (0.05) according to Duncan's Multiple Range Test.

Gerif soils significantly increased the shoot nitrogen content compared to Elrawakeeb soil. Elkhairat applied to Shambat soil significantly ($p \leq 0.05$) increased the shoot nitrogen content of faba bean. Abu floos, Elkhairat, EM, *Rhizobium*, and CM significantly ($p \leq 0.05$) increased the shoot phosphorus content of faba bean compared to the control (Table 6). Elrawakeeb soil significantly increased the shoot phosphorus content compared to Shambat and Gerif soils. *Rhizobium* applied to Shambat soil and Abu floos applied to Elrawakeeb soil showed the highest phosphorus content. Elkhaseeb, Elkhairat, *Rhizobium*, chicken manure and EM significantly ($p \leq 0.05$) increased the shoot potassium content of faba bean compared to the control (Table 6). Elrawakeeb and Gerif soils significantly increased the shoot potassium content compared to Shambat soil. The highest shoot potassium content was obtained when Elkhaseeb was applied to Gerif soil.

DISCUSSION

Effective microorganisms (EM)

Generally, application of EM in this study did not significantly increase the studied parameters of the tested crops grown in different soil types. Javaid and Bajwa (2011) reported that the effect of EM application on nodulation in legumes is highly variable, ranging from significantly negative to significantly positive, and they found that EM application alone had no effect but significantly enhanced shoot biomass of mung bean in the presence of NPK amendments. Moreover, Bajwa *et al.* (1995) stated that it is often difficult to establish the predominance of effective microorganism's cultures in soil with only a single application and during only one season because EM provides no nutrients directly. In addition, indigenous soil microbial populations are often constraints to the establishment of these microorganisms. However, these constraints could be overcome through periodically repeated applications of effective microorganisms at least during the first few years (Javaid *et al.*, 2000). Furthermore, source and amount of soil nutrients, soil type as well as the test crop may affect the establishment and efficacy of these microorganisms when application is started in a soil for the first time (Javaid and Shah, 2010).

Rhizobium

In this study *Rhizobium* inoculation significantly increased nodule number and dry weight of shoot and root in addition to nitrogen content of groundnut. Previously, similar results were obtained by Sulfab *et al.* (2011) and Singh *et al.* (2011).

Table 6. Effects of organic, chemical and biological fertilizers on nitrogen, phosphorus and potassium contents (%) plant of faba bean grown in three types of soils at ten weeks after sowing

				Fertilizers					
Soils	**Control**	**Urea**	**EM**	**Elkhaseeb**	**Elkhairat**	**Abu flous**	**CM**	**Rhizobium**	**Soil means**
				Nitrogen					
Shambat	2.26cdefgh	2.17defgh	1.47gh	3.47abc	3.50ab	2.84bcdef	2.17defgh	2.43bcdefgh	2.54A
Rawakeeb	1.47gh	2.45bcdefgh	2.17defgh	1.68fgh	1.21h	1.42gh	1.89efgh	2.19defgh	1.81B
Gerif	3.52ab	2.68bcdefg	2.07defgh	2.77bcdef	1.77fgh	4.08a	3.08abcde	3.29abcd	2.91A
Mean	2.41A	2.43A	1.90A	2.64A	2.16A	2.78A	2.38A	2.65A	
				Phosphorus					
Shambat	0.17defg	0.20cdef	0.17defg	0.16defg	0.14fg	0.16defg	o.15efg	0.34a	0.18B
Rawakeeb	0.11gh	o.17defg	0.25bc	0.16defg	0.22cd	0.34a	0.30ab	0.21cde	0.22A
Gerif	0.14fg	0.06h	0.11gh	0.20cdef	0.32a	0.19def	0.15efg	0.21cde	0.17B
Mean	0.14D	0.15CD	0.18BC	0.17BCD	0.23A	0.23A	0.20AB	0.20AB	
				Potassium					
Shambat	0.29h	0.35gh	0.35gh	0.41fgh	0.70d	0.35gh	0.32h	0.56def	0.41B
Rawakeeb	0.50efg	0.60de	1.06bc	1.11bc	0.99bc	1.34a	0.95c	1.01bc	0.94A
Gerif	0.96c	0.46efgh	1.00bc	1.35a	0.99bc	0.67d	1.15b	1.07bc	0.95A
Mean	0.58D	0.47D	0.80BC	0.96A	0.89AB	0.79C	0.80BC	0.88ABC	

Means followed by the same letter(s) are not significantly different at p≤ (0.05) according to Duncan's Multiple Range Test.

The nodule number of faba bean was not significantly affected by the *Rhizobium* inoculation. Increasing number of root nodules is not considered as a reliable parameter of efficient symbiosis between bacteria and host plant. A *Rhizobium* strain may form many nodules which are not effective in nitrogen fixation (Ali *et al.*, 1997). Other parameters are adopted for measuring the effectiveness of *Rhizobium* strains such as weight of plant (Beck, 1992), or plant nitrogen content (Moawad *et al.*, 1988).

Rhizobium inoculation significantly increased plant height, dry weights of shoot and root, phosphorus and potassium content of faba bean shoot. Inoculation is particularly important when local and indigenous soil rhizobial populations are either absent, present in very low numbers or not effective. When rhizobial population density is lower than 100 cfu per gram of soil, inoculation is likely to be beneficial for crop productivity. In such low population densities, inoculation would prove cost efficient regardless of the nitrogen fixation efficiency of the indigenous *Rhizobium* (Catroux *et al.*, 2001).

Rhizobium inoculation of faba bean significantly increased shoot and nodule dry weight and nitrogen content in shoot and yield (Mohamed and Babiker, 2012). Moreover, inoculation of faba bean with local or introduced cultures of *Rhizobium leuguminosarum bv. viceae* improved nodulation, plant growth and grain in Sudan (Rugheim and Abdelgani, 2009).

Manufactured organic fertilizers

In this study, results showed that application of different manufactured organic fertilizers (Elkhaseeb, Elkhairat and Abu floos) significantly increased most of the measured parameters for groundnut and faba bean.

Abdelhameed *et al.* (2004) reported that the application of compost significantly increased faba bean growth and yield. Moreover, compost showed a marked increase in nodulation, shoot, root and total biomass of groundnut (Singh and Jagadees, 2009).

Manna *et al.* (2001) found that matured compost significantly increased total P, water soluble P, citrate soluble P, total N and NO_3, whereas the application of phosphocompost at the rate of 10 t/ha improved plant growth, dry matter accumulation, seed yield and P uptake by soybean equivalent to a single dose of super phosphate at 26·2 kg P/ha. The continuous turnover of enriched phosphocompost increased soil microbial biomass C and the activity of enzymes compared to the application of chemical fertilizer.

CHICKEN MANURE

Generally, the results of the experiments in this study indicated that chicken manure significantly increased various growth parameters of the tested crops. According to Forawi and Eisheikh (1995), application of chicken manure increased nodulation, dry matter production and plant nitrogen content of fenugreek. Moreover, Ibrahim *et al.* (2011) found that chicken manure improved the dry weight of shoots and roots, nodulation, grain yield and yield components of hyacinth bean and soybean. Chicken manure was also reported to be a good source of N and P for the growth, nodulation and yield of some grain legumes, particularly soybean and cowpea (Tagoe *et al.*, 2010).

UREA

In this study, urea significantly increased nodule number, root and shoot dry weights of groundnut and root dry weight of faba bean. Generally, high doses of nitrogen reduced nodulation and nitrogenase activity of faba bean. Starter dose (10 kg N/ha) however, improved plant stand and enhanced nitrogen fixation and faba bean production (Mukhtar and Babiker, 1993). Pareek and Poonia (2011) found that increasing the level of nitrogen increased the number of pods per plant, shelling percentage, seed and yield of groundnut progressively up to 60 kg/ha applied in three doses.

CONCLUSIONS

According to the findings of this study, the following conclusions can be drawn:

1. Manufactured organic fertilizers (Elkhaseeb, Elkhairat and Abu floos) significantly increased most of the measured parameters in both crops compared to the control and other fertilizers.
2. Shambat soil showed the best growth performance for all measured parameters followed by Gerif and Elrawakeeb soils, respectively.
3. Effective microorganisms (EM) showed no significant improvements in most of the measured parameters for both crops compared to the untreated control.

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