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Effect of Bio-Organic Additives and Mineral Nitrogen Fertilizer Rates on Nitrogen, Phosphorus and Potassium Uptake by Sorghum with Aid of ^{15}N Stable Isotope

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ABSTRACT

A pot experiment was conducted in the green house to evaluate the response of sorghum crop grown on newly reclaimed sand soil to different organic additives in combination with biofertilizer *Azotobacter chroococcum* and different rates of mineral-N. Straw and root dry weight was stimulated by bacterial inoculation combined with high rate of mineral fertilizer (40 mg N pot^{-1}). Nitrogen uptake by straw and root was gradually increased with increasing fertilizer-N rates. Similar enhancement effect of organic fertilizers and bacterial inoculation was also recognized with high N rate. P uptake by plants was positively enhanced by nitrogen fertilizer application, compost and chicken manure additives. Reversibly, bacterial inoculation has no positive effect on P uptake by either straw or root. Potassium uptake was not varied as affected by organic additives. But, to some extent, it was enhanced by increasing the nitrogen fertilizer rates. Generally, bacterial inoculation has no positive effect on K uptake by either straw or root. Chicken manure was the best in releasing mineralized N (Ndforg) to inoculated plants, followed by leucaena residue then compost. In case of the un-inoculated plants, the release of N from chicken manure surpasses those of compost whereas leucaena residues came to the next. N derived from mineral fertilizer was significantly affected by mineral fertilizer rates and to some extent by organic types. Increases of %Ndff in the uninoculated plants confirmed its dependence mainly on N gained from mineral fertilizer rather than other sources like those derived from organic additives or soil.

Keywords: Bacterial inoculation, Nitrogen rate, ^{15}N, Organic additives, Sorghum

INTRODUCTION

Although chemical fertilizers have been claimed as the most important contributor to the increase in world agricultural productivity over the past decades (Smil, 2001), the negative effects of chemical fertilizer on soil and environment limit its usage in sustainable agricultural systems (Peyvast *et al*., 2008). Weakening soil quality requires increasing inputs to maintain high yields. This, in turn, threatens future food security and raises production costs for often already poor farmers.

Researches comparing soils of organically and chemically managed farming systems have recognized the higher soil organic matter and total nitrogen (N) with the use of organic agriculture. Soil pH becomes higher, plant-available nutrient concentrations may be higher, and the total microbial population increases under organic management (Dinesh *et al*., 2000; Lee, 2010).

Organic fertilizers, which mainly come from agricultural waste residues such as cow manure and spent mushroom compost or municipal solid waste compost (MSWC), are often identified as suitable local organic fertilizers. These contain high levels of nutrients, e.g. N and P and high amounts of organic matter (Peyvast *et al*., 2007, Peyvast *et al*., 2008; Olfati *et al*., 2008; Shabani *et al*., 2011). According to these studies, the usage of MSWC can be an effective alternative to chemical fertilizers. However, the apparent deficiency of an adequate supply of plant-available N from organic fertilizer, resulting from a slow rate of mineralization, makes crop yields in fields treated with organic fertilizer lower than in those treated with chemical fertilizers (Lee, 2010). Organic fertilizers should be used in appropriate amounts to achieve suitable yield and quality.

The use of organic fertilizers can avoid or reduce the deleterious effects attributed to the use of chemical fertilizer. Applying chemical fertilizer leads to the deterioration of soil characteristics and fertility, and as well it leads to a reduction in fruit nutrition values and edible qualities (Shimbo *et al*., 2001). It also reduces the dry matter content of tomatoes (Marzouk and Kassem, 2011). The continuous use of chemical fertilizers may also lead to the accumulation of heavy metals in plant tissues which compromises the nutrition value and fruit quality (Shimbo *et al*., 2001). Although it is reported that the supply of plant-available N from organic fertilizer, resulting from a slow rate of mineralization, makes crop yields in fields treated with organic fertilizer lower than in those treated with chemical fertilizer (Lee, 2010). In addition, low nutrient availability limits the crop growth (Vyas *et al*., 2003). There is a little available N, the strong P fixation results in moderate P availability, and the same applies to available K even though total K is high (Tolanur and Badnur, 2003). Recent escalation of prices of raw materials and energy for fertilizer production threatens the economic profit from increased use of fertilizers by the farmer, especially under dryland farming. This has resulted in reduced use of fertilizer and persistent nutrient depletion from these soils, posing a further threat to sustainable agriculture. Organic manures (crop residues and twigs of trees), composts and biofertilizers improve the physical, chemical and biological properties of the soil, and in addition improve the efficient use of applied fertilizers (Durgude *et al*., 1996).

This study aimed at recognizing the benefits from organic wastes and bio-inoculant in combination with rates of chemical fertilizer in improvement of sorghum growth and nutrients acquisition.

MATERIALS AND METHODS

Pot experiment was conducted in greenhouse of Soil and Water Research Department, Nuclear Research Center, Atomic Energy Authority, Inshas, Egypt. This experiment was carried out to elucidate the effect of bio-organic fertilizers as well as mineral-N rates on growth, phosphorus and potassium uptake by sorghum crop. Experimental work consists of three organic amendments, two mineral-N rates, in addition to unfertilized control, combined with/without *Azotobacter chrooccocum* inoculation.

Compost (C), chicken manure (CM), and Leucaena trees cutting residue (*Leucaena leucocephala*) (L) were applied as organic amendments. Some chemical characteristics of selected organic amendments are presented in Table (1).

Table 1. Chemical characteristics of compost, chicken manure and Leucaena residues.

Character	Compost	Chicken manure	Leucaena residue
C/N ratio	12	14	18
OM%	56.9	39.9	43.7
N%	2.8	0.9	5.3
P%	0.8	0.5	0.3
K%	0.7	0.5	2.7
Fe µg g^{-1}	2898	2730	890
Cu µg g^{-1}	212	148	118
Zn µg g^{-1}	155	223	117

Efficient strains of *Azoobacter chroococcum* provided by the Agricultural Microbiology Department, Institute of Soil, Water and Environment, Agriculture Research Center at Giza, Egypt, were used for sorghum inoculation. The inoculum has 8 x 109 cells g-1peat. The sticking of inoculums carrier to sorghum grains was carried out according to Somasegaran and Hoben (1994).

Sorghum (*Sorghum bicolor* var. bicolor) plants were fertilized with N at rates of 50 and100 mg N kg-1 soil (equal to 200 and 400 mg N pot-1, respectively) in the form of ammonium sulfate. Also, unfertilized treatment was included. 15N-Labeled ammonium sulfate (2% 15N atom excess) was applied as a source of mineral nitrogen (ammonium sulfate) one time after two weeks from planting. Nitrogen stable isotope technique was processed according to IAEA - TECDOC series no 14 (2001). Nitrogen derived from organic sources was estimated using the following equation,

$$\%Ndorg = (1- {}^{15}N\%\ a.e.\ in\ treated\ sample/\ {}^{15}N\%\ a.e.\ in\ untreated\ control) \times 100$$

$$\%\ Ndff = \frac{\%\ {}^{15}N\ atom\ excess\ in\ plant}{\%\ {}^{15}N\ atom\ excess\ in\ fertilizer} \times 100$$

$$Nydff = \%Ndff \times total\ N\ uptake.$$

$$\%\ NUE = \frac{Nydff}{Rate\ of\ fertilizer\ applied} \times 100$$

Plastic pots were uniformly packed with portions of air-dried and screened soil (4 kg pot-1). Some physical and chemical characteristics of experimental reclaimed sand soil are presented in Table (2). Physico-chemical analyses of soil samples were determined according to Carter and Gregorich (2008).

Table 2. Some physical and chemical characteristics of reclaimed sandy loam soil.

Mechanical analysis				Texture	Bulk density (g/cm3)	Moisture content by volume (%)			Organic Matter (%)
Clay (%)	Silt (%)	Sand (%) Coarse	Sand (%) Fine			F.C	W.P	A.W	
16.5	5.5	14.3	63.7	SANDY LOAM	1.3	25.1	9.3	15.8	0.03
Ec (dsm^{-1})	pH	Soluble anions (meq/l)				Soluble cations (meq/l)			
		CO_3^-	HCO_3^-	Cl^-	SO_4^{--}	Ca^{++}	Mg^{++}	Na^+	K^+
0.4	8.2	-	2.2	1.7	0.1	1.5	1.8	0.6	0.1

Basic supplemental of P and K fertilizers were applied to each pot at the rate of 200 mg kg-1 soil as supper phosphate (200 kg fed-1) and at the rate of 50 mg kg-1 soil as potassium sulfate (50 kg fed-1), respectively. Afterwards, the soil was lightly irrigated by about 60% of water holding capacity (WHC) to establish good microbial activity for decomposing plant residues in suitable time before sowing sorghum seeds. Each pot was sown with 8 sorghum seeds, which were thinned to 4 plants after 14 days from planting. The pots were arranged into two groups, each of which conducted in a completely randomized block design with three replicates.

Sorghum plants were harvested after 107 days from sowing and separated into straw and roots and the following data were recorded. Samples of sorghum shoots and roots were taken and oven dried at 70 °C for 24 hours to determine the dry weight hence ground to digest in concentrated H2SO4 and H2O2. After digestion of plant shoots and roots, samples were analyzed to determine nitrogen, phosphorus and potassium in shoot and roots according to Estefan *et al.*, (2013). The obtained data were subjected to statistical analysis according to SAS software (ANOVA analysis), (2002).

RESULTS AND DISCUSSION

Dry matter yield

Straw and root dry weights were significantly positively affected by inoculation treatment (Table 3). This holds true with all fertilization rates. Both organs dry weight tended to increase with increasing N fertilizer rate. Highest values were recorded with addition of 400 mg N pot-1. In conclusion, straw and root dry weight was stimulated by bacterial inoculation combined with high rate of mineral fertilizer (100%). Concerning the organic sources, the stimulated effect could be ranked as: compost > chicken manure ≥ leucaena residue in case of straw of uninoculated plants. In case of inoculated one, organic sources could be ranked as: chicken manure = leuceana residue > compost. Root dry weight was enhanced by addition of chicken manure, leuceana residues then compost. Dry weight of straw was higher than those recorded for root under all studied factors.

On line, Patil and Sheelavantar (2006) screened organic materials and found, among them, application of *Leucaena* loppings at 2.5 Mg ha_1 proved beneficial in marginally improving soil properties, increased biomass production and grain yield during both the years of study by 9% (pooled) compared to vermicompost applied at 1.0 Mg ha_1. Increase in N application up to 25 kg ha_1, increased the grain yield (1620 kg ha_1) significantly ($P < 0.05$) by 18% over control, increased N applications to 50 kg ha_1 increased the grain yield significantly over 0 and 25 kg N ha-1.

Dealing with effect of inoculation, Badr *et al.* (2006) found that the dry matter of sorghum plants inoculated with silicate dissolving bacteria (SBS strain) and supplied with minerals (feldspar and rock phosphate) increased by 65% for sandy soil, compared to the plants supplied with minerals solely. These results are in agreement with us and those of Gad (2001) who reported that biofertilization of plants resulted in an increase in plant growth and yield production. Also, Abou El Seoud *et al.* (2009) reported that the phosphate dissolving bacteria (PDB) have a significant effect on root yield. The root yield of sugar beet varieties inoculated with PDB was higher by about 19.8% and 20.2% than the uninoculated plants.

Table 3. Effect of bacterial inoculation, organic amendments and N-fertilizer rates on sorghum dry matter yield (g pot^{-1}).

Bio-organic Treatments		Mineral nitrogen rates mg pot^{-1}					
		0		200		400	
		Straw	Root	Straw	Root	Straw	Root
Chicken	Uninoc	85.9 f	36.1 ef	103.3 cd	47.7 bc	122.5 ab	61.4 ab
manure	Inoc	101.2 de	39.7 de	119.4 bc	57.9 ab	134.4 ab	64.1 a
Compost	Uninoc	90.8 ef	30.1 g	103.8 b	46.3 cd	113.8cd	50.3 ab
materials	Inoc	97.1 ef	32.8 fg	105.7 cd	50.0 ab	123.8 ab	59.1 ab
Leucaena	Uninoc	89.1 f	31.4 g	101.3 de	43.3 de	120.6 ab	53.0 ab
residues	Inoc	101.2 de	36.2 ef	119.2 bc	52.4 ab	142.0 a	63.2 a

Means in the same column followed by the same letter are not significantly different at $P \leq 0.05$

Nitrogen uptake

Unfertilized plants showed significant responses to organic fertilizers and bio-inoculation (Table 4). Both straw and root N uptake was enhanced by inoculation. Values were higher with chicken manure addition than leuceana residue and compost. Nitrogen uptake by straw and root was gradually increased with increasing fertilizer-N rates. Similar enhancement effect of organic fertilizers and bacterial inoculation was also recognized with high N rate. More nitrogen was accumulated in straw than root. The relative increments in straw-N uptake were 28%, 116% for 50% and 100% N rates for the uninoculated but chicken manure treated plants. For root, it accounts for 75%, 124% for the same sequence.

Table 4. Effect of bacterial inoculation, organic amendments and N-fertilizer rates on nitrogen uptake by sorghum (g pot^{-1}).

Bio-organic Treatments		Mineral nitrogen rates mg pot^{-1}					
		0		200		400	
		Straw	Root	Straw	Root	Straw	Root
Chicken	Uninoc	890.4b	392.3b	1142.4cd	687.4ab	1922.5ab	878.7b
manure	Inoc	1084.3a	483.0a	1579.3a	754.3a	2244.4a	1142.8a
Compost	Uninoc	736.6de	300.8cd	1172.8c	523.3c	1422.0cd	706.5cd
materials	Inoc	811.0d	367.4c	1302.3b	686.5ab	1952.1b	858.4b
Leucaena	Uninoc	866.7bc	222.4ef	1185.2c	536.6c	1566.1c	862.6b
residues	Inoc	1054.1a	440.7ab	1439.9ab	707.0ab	2025.7ab	1165.0a

Means in the same column followed by the same letter are not significantly different at $P \leq 0.05$

Phosphorus uptake

Plants treated with chicken manure did not reflect significant difference between inoculated and uninoculated one when P uptake by either straw or root was considered (Table 5). Nitrogen applied at 400 mg pot-1 increased P uptake by straw over those recorded with unfertilized control. On the other hand, there was no remarkable difference between P uptake by root of uninoculated plants as affected by fertilization factors. Similar trend was noticed with the inoculated plants. Phosphorus uptake by straw and root as affected by compost additives were nearly closed to those resulted in with chicken manure additions. Also, inoculation has no remarkable positive effect on P uptake. Severe reduction in P uptake by straw or root was noticed with leuceana residues added to the unfertilized treatment. In this regard, high P uptake by root was recorded with application of both N-fertilizer rates comparable to those recorded with the unfertilized one. In general, P uptake by plants was positively enhanced by nitrogen fertilizer application, compost and chicken manure additives. Reversibly, bacterial inoculation has no positive effect on P either taken by straw or root.

Potassium uptake

Chicken manure interacted with high rate of nitrogen fertilizer induced, to some extent, increase in K uptake by straw and root of sorghum plants. Inoculation resulted in slight increase of K uptake especially with root and straw of plants treated with 400 mg N pot-1. Treatment of 200 mg N pot-1 came to the next comparing to the unfertilized control. Potassium uptake by straw and root of compost treated plants has almost the same trend. In this respect, values were nearly closed to those recorded with chicken manure and leuceana residues additives (Table 6).

Table 5. Phosphorus uptake by straw and root of sorghum (g kg^{-1}) as affected by bio-organic additives or mineral fertilizers rates

Bio-organic Treatments		Mineral nitrogen rates mg pot^{-1}					
		0		200		400	
		Straw	Root	Straw	Root	Straw	Root
Chicken	Uninoc	7.524a	20.826a	3.162b	11.286bc	13.635bc	20.430a
manure	Inoc	5.163a	19.759a	3.078b	12.197bc	22.299a	19.903a
Compost	Uninoc	6.541a	15.277ab	5.283a	16.344b	16.080bc	21.688a
materials	Inoc	4.875ab	16.14ab	4.156ab	15.277b	12.150bc	23.654a
Leucaena	Uninoc	2.419c	3.533de	2.539de	25.308a	5.163ef	23.989a
residues	Inoc	1.640de	7.716c	3.330d	23.318a	5.343ef	23.486a

Means in the same column followed by the same letter are not significantly different at $P\leq 0.05$

Agegnehu *et al.*, (2016) explained that significantly higher yield and plant biomass on organic-amended plots was due to increased nutrient uptake and perhaps increased water uptake and transpiration by the plants over their growth cycle. They added that increase in the shoot N content of barley with organic amendments was similar to that resulting from N fertilizer addition. However, plant P and K concentrations were higher for organic-amended than N fertilized soil, suggesting that organic treatments improve the supply of other essential macro- and micro-nutrients and water. Although shoot N, P and K concentrations were in the reported sufficiency range for all treatments (Jones, 2003), the trial site Holetta with the higher yield, C and N in the soil had mean shoot N and K content of 3.19 and 3.63% for Com and 3.22 and 3.57% for the 92 kg N ha-1 compared to shoot N and K content of 2.12 and 2.39% for Com and 2.13 and 2.43% for 92 kg N ha_1 at Robgebeya. This indicates that the application of organic amendments influences directly the availability of native or applied nutrients. The plant nutrient content at Holetta was higher than at Robgebeya, reflecting differences in yield and soil fertility between the sites. However, in the long term, organic amendments and fertilizer may have substantial effects at less fertile sites. The trend in plant N uptake increases in relation to organic amendments and N levels were similar to the increments in plant growth, yields and soil nutrient status.

Table 6. Potassium uptake by straw and root of sorghum (g kg^{-1}) as affected by bio-organic additives and mineral fertilizers rates

Bio-organic Treatments		Mineral nitrogen rates mg pot^{-1}					
		0		200		400	
		Straw	Root	Straw	Root	Straw	Root
Chicken	Uninoc	4.084a	4.507c	6.961a	8.738b	8.823b	11.108c
manure	Inoc	5.100a	7.554a	6.877a	9.161b	12.715a	17.200a
Compost	Uninoc	4.338a	5.015bc	5.100b	10.938a	6.115bc	12.123b
materials	Inoc	4.677a	5.777bc	5.523b	11.108a	6.538bc	12.885b
Leucaena	Uninoc	4.084a	6.115b	4.677bc	7.638c	5.354c	12.123b
residues	Inoc	4.592a	6.369b	4.761bc	11.362a	5.438c	13.985b

Means in the same column followed by the same letter are not significantly different at $P\leq 0.05$

Replenishment of organic matter derived from plant, animal and microbial biomass in all stages of decomposition is critical to ensuring long-term soil fertility; it provides a balanced medium for nutrients and water for plant growth. Although significant quantities of manures and crop residues are produced as potential feedstock for biochar and compost production, they are not returned to soil due to competing utilization. For example, some estimates suggest the nutrient contents of the crop residues used as feed and manures as fuel instead of fertilizer are higher than the quantities applied as fertilizers, in other words, this lack of alternative fuel and feed sources is a significant constraint to productivity and sustainability of the broader agricultural system in the highlands (Zelleke *et al.*, 2010). Application of biochar and biochar-compost mixes could potentially decrease the N fertilizer requirement for crop growth. Decreasing N fertilizer application rate can, in turn, reduce the cost of producing food, while simultaneously mitigating environmental pollution. The effective use of organic resources as nutrient sources is central to achieving the long-term need for increased biomass production for food and soil fertility, and hence sustainably higher productivity, critical to breaking the poverty cycle. Specific actions include improving the local supply of affordable fuel alternatives, efficiency of stoves and availability of affordable feed and forage sources. Overall, the integrated use of all the available resources including lime and organic amendments to improve and sustain soil health and crop yield is of great practical significance.

Under conditions given in the study of Abou-el-Seoud and Abdel-Megeed (2012), co-inoculation of PSB and KSB in conjunction with direct application of rock P and K materials into the soil had increased growth of maize plants grown on P and K limited soils and enhanced P and K availability and uptake by the tested plant. Many researchers explained that this enhancement may be attributed to the ability of *B. megaterium* to produce some growth promoting substances such as IAA, gibberellins and abscisic acid, it is also well known that *B. megaterium* produces organic, inorganic acids and CO2 which lead to increase in soil acidity and consequently convert the insoluble forms of phosphorus into soluble ones (Wani *et al.*, 2007). In addition, increasing plant dry matter due to inoculation with PDB was attributed to the reduction of media pH and hence the solubility of phosphates (Adesemoye and Kloepper, 2009).

Nitrogen derived from organic sources (%Ndforg)

Portion of nitrogen derived from organic additives as affected by fertilizer rates, bacterial inoculation under different organic sources and soils was presented in Table (7). The percentages of N derived from different organic additives under arable reclaimed sandy loam soil, the portion of N derived from organic resources by straw and roots was fluctuated according to organic type and bacterial inoculation as well as mineral fertilizer rates. In this respect, chicken manure was the best in releasing mineralized N followed by leucaena residue then compost when plants inoculated with *Azotobacter chroococcum*. The un-inoculated plants showed that release of N from chicken manure surpass those of compost and leucaena residues.

Compost applied to the un-inoculated plants was most effective on releasing N under arable reclaimed sandy loam soil. The same effect was detected with N derived from chicken manure. Mineralization of leucaena came to the next. It means that release of nitrogen from the organic sources was dependent on its origin is and significantly related to mineral fertilizer rates as well as the presence or absence of biofertilization treatments (bacterial inoculation).

Nitrogen Derived From Fertilizer (Ndff)

The portions of N derived from mineral fertilizer by straw were enhanced with the uninoculated treatment comparing to the inoculated one. This holds true under all nitrogen fertilizer rates. On the other hand, they were higher in case of 100 unit of nitrogen fertilizer rate than those of 50 unit N fertilizer rate. Similar trend was noticed with root system. In this respect, there was no significant difference between straw and roots. In some cases %Ndff by straw showed a slight increases over those found in roots (Table 8). Compost, chicken manure and leucaena residue doesn't reflect significant difference. It seems that the portion of nitrogen derived by stalks or roots mainly affected by mineral fertilizer rates and bacterial inoculation rather than organic additives. Despite of N rates, the mean average of %Ndff was significantly affected by organic additives where it was higher in case of compost and leucaena residue than chicken manure.

Table 7. Percent of nitrogen derived from organic resources as affected by bacterial inoculation and different rates of mineral nitrogen fertilizer.

Mineral-N Rates	Organic additives											
	Compost				Chicken manure				Leuceana			
	Straw		Root		Straw		Root		Straw		Root	
	%	mg	%	mg	%	mg	%	mg	%	mg	%	Mg
	Inoculated											
200	25.0	93.0	25.0	146.6	65.4	390.6	41.2	203.6	36.5	124.1	40.4	164.4
400	41.4	198.0	35.5	198.2	40.2	259.0	36.4	212.0	46.5	188.3	39.6	223.7
Mean	33.2	145.5	30.3	172.4	52.8	324.8	38.8	207.8	41.5	156.2	40.0	194.0
	Un-inoculated											
200	21.1	78.7	15.4	80.5	44.2	261.8	57.7	281.0	17.3	49.3	15.4	82.6
400	31.0	141.5	60.2	110.4	36.2	225.3	50.0	289.0	20.7	75.7	23.6	132.7
Mean	26.1	110.1	37.8	95.4	40.2	243.5	53.8	285.0	19.0	62.5	19.5	107.6

Table 8. Percent and absolute value of nitrogen derived from mineral fertilizer as affected by bacterial inoculation, organic amendments and different rates of mineral nitrogen fertilizer

Mineral-N Rates	Organic additives											
	Compost				Chicken manure				Leuceana			
	Straw		Root		Straw		Root		Straw		Root	
	%	mg	%	mg	%	mg	%	mg	%	mg	%	Mg
	Inoculated											
200	22.0	81.9	22.0	129.0	10.0	59.7	11.0	54.4	18.0	61.2	17.0	69.2
400	19.0	90.8	7.0	39.1	11.0	70.9	10.0	58.3	17.0	69.0	19.0	107.4
Mean	20.5	86.4	14.5	84.1	10.5	65.3	10.5	56.6	17.5	65.1	18.0	88.3
	Un-inoculated											
200	23.0	85.7	24.0	125.6	16.0	94.8	12.0	58.5	24.0	68.4	24.0	128.8
400	22.0	100.4	13.0	71.0	21.0	130.7	16.0	92.6	26.0	95.2	25.0	140.7
Mean	22.5	93.1	18.5	98.3	18.5	112.8	14.0	75.5	25.0	81.8	24.5	134.7

In conclusion, the portion of N derived from mineral fertilizer was significantly affected by mineral fertilizer rates and to some extent by organic types. Increases of %Ndff in the uninoculated plants confirmed its dependence mainly on N gained from mineral fertilizer rather than other sources like those derived from organic additives or soil. It was proved that changes in Ndff are attributed to the exogenous additives, i.e. mineral and organic as well as biological one.

Nitrogen use efficiency NUE

Sorghum inoculated with *Azotobacter chroococcum* and treated with compost showed more efficient use of N by straw as compared to roots (Table 9). This phenomenon was more pronounced with 50 units N fertilizer where the percent NUE by stalks doubled those of roots, while with 100 units N fertilizer, %NUE of straw and roots were nearly closed to each other. Similar trend, but to somewhat lower extent, was noticed with incorporation of leucaena residues. Reversible trend was noticed with chicken manure where %NUE by roots was higher than those of straw especially when 50 units N fertilizer was considered. Uninoculated plants showed, to some extent, the same trend but fluctuated in relation to mineral fertilizer rates. The mean average of %NUE reflected higher percentages of the uninoculated plants than those recorded with inoculated plants.

Table 9. Nitrogen use efficiency (NUE%) by different plant parts as affected by bacterial inoculation, organic amendments and different rates of mineral nitrogen fertilizer

Mineral -N Rates	Organic additives					
	Compost		Chicken manure		Leuceana	
	Straw	Root	Straw	Root	Straw	Root
			Inoculated			
200	41.0	64.5	29.9	27.2	30.6	34.6
400	22.7	9.8	17.7	14.6	17.2	26.8
Mean	31.8	37.2	23.8	20.9	23.9	30.7
			Un-inoculated			
200	42.9	62.8	47.4	29.2	34.2	64.4
400	25.1	17.8	32.7	23.1	23.8	35.2
Mean	34.0	40.3	40.1	26.2	29.0	49.8

The effect of organic additives on %NUE, despite of plant organs, resulted in the superiority of compost over chicken manure and leucaena residues, respectively. This holds true with either inoculated or uninoculated plants but NUE still high in uninoculated ones. The inoculated plants used nitrogen more efficiently when treated with compost followed by leucaena residues then chicken manure. On the other hand, NUE by uninoculated plants was higher in case of leucaena residues than those treated with compost and chicken manure, respectively.

The enhancement of sorghum growth and nutrients acquisition were previously explained by Patil (2014) who stated that organic additives conserved more water and in the same time *Azospirillum* seed inoculation produced 13% more sorghum grain and straw yield comparing to the unfertilized control. On line, he found that application of 50% recommended rate of urea plus 50% leuceana loppings + farm yard manure in combination with *Azospirillum* resulted in 44% increase in grain yield comparable to control. In addition, he recommended application of organic-N and fertilizer (50:50) along with *Azospirillum* for sustainable sorghum yields.

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تأثير الاضافات العضوية الحيوية ومعدلات النيتروجين على امتصاص النيتروجين والفوسفور والبوتاسيوم بواسطة الأذرة الرفيعة بمساعدة النظير المستقر – ن^{15}

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قد اجريت تجربة اصص بالبيت المحمي لتقييم أستجابة نبات الذرة الرفيعه النامي في الأراضي الرملية حديثة الإستصلاح لمستويات مختلفه من الإضافات العضوية والحيوية مع معدلات مختلفة من السماد النتروجيني. حيث كان تصميم التجربة في قطع منشق مرتين وكررت كل معاملة ثلاثة مرات ، واشتملت القطع الأولية علي إضافات عضوية (كمبوست، مخلفات دواجن ومخلفات أشجارالليوسينا)، والقطع الثانوية تمثل بدون أو مع إضافة بكتريا والقطع تحت الرئسية مثلت بثلاث مستويات من السماد النتروجيني (0، 50 و 100ملجم/كجم تربه). أظهرت النتائج أن هناك استجابه عاليه لإمتصاص النتروجين والفوسفوروالبوتاسيوم الممتص بواسطه القش والجذور في نباتات الذرة الرفيعه نتيجة تسميدها بمستويات عاليه من النتروجين. كما أوضحت النتائج أن هناك استجابه عاليه لإمتصاص النتروجين والفوسفور نتيجة التسميد بالكمبوست ومخلفات الدواجن مع السماد النتروجيني والحيوي ولكن لوحظ ان التسميد الحيوي لم يؤثر علي إمتصاص الفوسفور بواسطة أجزاء النبات. كما وجد انه لم تظهر استجابه لامتصاص البوتاسيوم بواسطة قش أو جذور النبات تحت تأثير الإضافات العضوية والحيويه. كانت مخلفات الدواجن الأفضل من حيث انسياب النيتروجين الممعدن منها (المستمد من الصورة العضوية)، يتبعها المنساب من بقايا الليوسينا ثم الكمبوست. في حالة النباتات غير الملقحة، كان انسياب النيتروجين العضوى من مخلفات الدواجن يفوق المنساب من الكمبوست ثم أتت بقايا الليوسينا في المؤخرة. النيتروجين المستمد من السماد المعدنى تأثر معنويا بمعدلات الاضافة من السماد الكيماوى والى حد ما بنوعية المحسنات العضوية. الزيادة في النيتروجين المستمد من السماد المعدنى في المعاملات غير الملقحة أكد اعتماد النبات على هذا المصدر بصفة رئيسية عن تلك المستمدة من المصادر الأخرى مثل المحسنات العضوية.