EG0800363

Influence of organic N Sources on N transformation and uptake by lupine plants using ^{15}N technique

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ABSTRACT

A pot experiment was carried out under greenhouse conditions to evaluate the comparative efficiency and transformation of nitrogen applied either as mineral or organic forms. The obtained data showed that shoot dry weight was enhanced by compost and its mixture with leucaena. When organic sources were combined with ^{15}N, the leucaena–compost mixture (LC_p) gave the highest yield, and the other two were not significantly different from each other. Reinforcing the organic N with mineral N caused an average greater N–uptake over the non reinforced treatment. Similar trend was noticed with root system. Nitrogen uptake by roots was increased according to the order of LC > L > C. N derived from fertilizer (% Ndff) by lupine shoots was significantly affected by fertilizer addition either alone or reinforced with organic plant residues. Both, the portions (%) or absolute values (mg pot^{-1}) of Ndff were increased by adding the organic residues. The highest value of Ndfs was recorded with application of leucaena followed by compost, then Leucaena+compost. Portion Ndfa reflected an effective response of lupines plants to *Rhizobium* inoculation. Addition of LC mixture combined with ^{15}N-fertilizer had enhanced the N_2 fixation and increased Ndfa value by about 66.7 % over those recorded with $^{15}N0$ treatment. Organic amendment of leucaena could be an efficient source for N to infertile sandy soils.

Key words: Lupine, Leucaena / Organic N / N-15 technique

INTRODUCTION

Straw of cereal crops (such as sorghum, maize, wheat and rice) as well legume crops, stalks of cotton and residues of other fiber crops are major sources of organic matter in soils. Other, plant parts such as cuttings resulting from pruning of trees, and shrubs (such as leucaena and acacia and) are important sources of soil organic matter [(1)]. Green manuring of a sandy soil using leucaena pruning led to enrichment with plant nutrients and increased maize production [(2)]. Khalil et al., [(3)] mentioned that decomposition of added organic materials is soil specific and depends largely on chemical composition of soil and material types.

Shindo and Nishio [(4)] using ^{15}N tracer, showed that within 15 days following addition of wheat straw to soils, a rapid decrease in nitrate N and a rapid increase in microbial biomass N as well as biomass C occurred. A recovery of applied organic-N amounting to 16.2 % was obtained by Ichir and Ismail, [(5)] when the organic residues was mixed with mineral N. They added that loss of organic N was mainly due to denitrification rather than leaching. Jung et al. [(6)] studied the application of organic manure and effect on the fate of inorganic–N in soil under vegetable crops. They found that immobilization of added inorganic ^{15}N was enhanced by manure. Fosu et.al [(7)] reported that it is important to quantify the fate of the applied organic-N to understand the efficiency of residue-N use and to estimate the minimum input required to obtain a reasonable level of crop response.

This work aims at tracing the transformation of nitrogen in organic materials containing N as source of nitrogen which may help in improving plant growth as well as soil fertility.

MATERIALS AND METHODS

Pot experiment was performed using a sandy soil (88.5%sand) collected from Inshas. Some physical and chemical characteristics of the soil are given in Table (1). Pot each (30 cm height, 28 cm depth) filled with 5 kg soil. All pots received P and K at the rate of 20 and 45 mg kg^{-1} soil in the form of "K_2HPO_4". Fe, Mn, Zn, and Cu as EDTA were added at rates 20, 10, 5 , and 3 mg kg^{-1} and B as borax (0.3 mg kg^{-1}). N was added in form of $^{15}(NH_4)_2SO_4$, "21.1 % nitrogen" with enrichment of 5% ^{15}N atom excess. N fertilizers was added at the rate of 10 mg kg^{-1} soil; given either as mineral or organic.

Composted organic materials consist of mixture of various organic residues (plant and animal residues), and cutting residue were used. The chemical analysis of the compost and leucaena are presented in Tables (2 & 3) .

Table (1): Physical and chemical characteristics of the Inshas sandy soil used.

Particle size distribution					Soluble ions (in saturation extract)							
					Cations $mmol_c/L$				Anions $mmol_c/L$			
Coarse sand %	Fine sand %	Silt %	Clay %	texture	Ca^{2+}	Mg^{2+}	Na^+	K^+	CO_3^{2-}	HCO_3^-	Cl^-	SO_4^{2-}
64.1	24.4	2.7	8.8	Sandy	15.20	4.60	2.17	0.89	0.00	3.46	6.50	12.90

pH	WHC	Organic matter gkg^{-1}	$CaCO_3$ %	E.C. $dS.m^{-1}$	CEC $cmol_c\ kg^{-1}$	Available nutrients mg kg^{-1}		
						N	P	K
7.1	15	0.3	1.0	2.3	6	5	2	0. 2

Table (2): Some chemical characteristics of the composted materials used

Chemical properties				Content of total forms of nutrients g kg-1								
Organic Matter%	Total C %	Total N %	C / N	P	K	Na	Ca	Mg	Zn	Fe	Mn	Cu
32.9	19.1	1.25	15	3.5	7.2	69.0	47.0	20.0	4.0	19.0	27.0	1.0

Table (3): Chemical analysis of leucaena used .

Chemical properties				Content of total forms of nutrients g kg-1								
Organic Matter %	Total C %	Total N %	C / N	P	K	Na	Ca	Mg	Zn	Fe	Mn	Cu
92.0	53.49	4.09	13.1	17.8	8.0	1.8	25.0	20.0	0.4	2.2	0.2	0.1

Five seeds of lupine were planted in each pot. The pots were arranged into two groups, each of which conducted in a completely randomized block design with four replicates. After 50 days, plants were harvested, dried at 70 ^0C , ground and kept for analysis. Samples of dry plant material were wet digested using the method described by Bremner and Mulvaney, [8].

Results and Discussion

Dry matter

Applying nitrogen gave increases in plant weight ranging from 24.7 % (L_t) to 95.6 % (LC_p). The totally mineral ^{15}N showed 45.8 %. The totally organic N showed an increase averaging 42.6 %. The partially organic–partially mineral showed much greater increase of 74.2 %. Therefore presence of organic N along with mineral N enhanced the positive response of plant growth to mineral nitrogen application (Table 5).

The main effect shows that compost and its mixture with leucaena gave the highest weight. The main effect of the organic sources show LC ≥ C > L. However there was an interaction caused by the status of N. Where nitrogen was given totally as organic with no reinforcement, the compost (C_t) form was superior to the leucaena (L_t) as well as to leucaena–compost mixture (LC_t). Increases of C_t and LC_t over L_t were 30.9 and 11.2 %, respectively. This indicates that the compost was a source of N of greater efficiency than leucaena. The compost being a material of greater biological activity demonstrated its superiority over leucaena.

Table (5) Dry matter of Lupine plants (g/pot) as affected by organic N sources and/ or ^{15}N mineral.

Reinf. with ^{15}N (N)	Organic source (O)			Mean
	Leucaena (L)	Compost (C)	Mixture (LC)	
	Shoot			
without ^{15}N	3.43	4.49	3.83	3.92
with ^{15}N	4.47	4.52	5.38	4.79
mean	3.95	4.51	4.61	
	Root			
without ^{15}N	2.89	2.20	1.89	2.33
with ^{15}N	3.51	2.57	5.24	3.77
mean	3.20	2.39	3.57	
LSD (0.05)	Shoot		Root	
N	0.150		0.066	
O	0.183		0.081	
NxO	0.259		0.115	

On the other hand where the organic sources were reinforced with ^{15}N, the leucaena–compost mixture (LC_p) which gave the highest yield, and the other two were not significantly different from each other. The (LC_p) treatment surpassed the (L_p) and (C_p) treatment by 20.4 and 19.0 %, respectively.

Our results, in most cases, are in harmony with those obtained by Rahman et. al. [9] who found that the rice yield and recovery of ^{15}N fertilizer were significantly increased by addition of legume residues. Their results show that legumes N can supply a substantial proportion of the N requirements of wetland rice and in the same time can reduce the nitrogen losses which were lower than those obtained with a single application of labeled fertilizer.

Applying nitrogen gave increases in root dry weight ranging from 35.0 % LCt to 174.3 % LCp. The mineral ^{15}N shows an increase of 120.7 %. Average increase of the organic N is 66.4 %. Average increase of the partially organic–partially mineral (i.e. the organic source combined with mineral ^{15}N) is 169.3 %. Combination of organic N with mineral ^{15}N is thus of considerable positive effect in root growth.

The main effect of the organic sources shows C >L > C; with compost and its mixture with leucaena having similar effect, on average. The main effect of combination shows that combining the organic N with mineral ^{15}N caused an average greater weight of roots amounting to 15.9 % over the non combined treatment.

Superiority of the leucaena-compost mixture was most prominent and considerable under conditions of N combination when it surpassed individual leucaena or compost by 49.3 and 103.9 %, respectively.

Nitrogen-uptake by lupine

Table (6) show the effect on the nitrogen uptake in lupine shoots. Applying nitrogen in any of the forms and whether the dose was entirely mineral, or entirely organic or half mineral + half organic, caused increases in N-uptake by lupines shoots ranging from 191.6 % LC_t to 353.5 % LC_p. The main effect of the organic sources reflected the following order: LC > C ≥ L.

The main effect of combination shows that combining the organic N with mineral N caused an average greater N-uptake over the non combined treatment amounting to 46.1%.

Table (6) Nitrogen uptake by lupine plants (g/pot) as affected by organic N sources and/ or ^{15}N mineral.

Reinf. with ^{15}N (N)	Organic source (O)			mean
	Leucaena (L)	Compost (C)	Mixture (LC)	
	Shoot			
without ^{15}N	47.68	48.94	53.62	50.08
with ^{15}N	70.63	65.54	83.39	73.19
Mean	59.16	57.24	68.51	
	Root			
without ^{15}N	27.10	25.14	26.81	26.35
with ^{15}N	32.64	16.96	34.06	27.89
Mean	29.87	21.05	30.44	
LSD (0.05)	Shoot		Root	
N	2.997		1.273	
O	3.670		1.559	
N X O	5.191		2.204	

Superiority of LC was particularly observed when the organic sources were combined with mineral ^{15}N. Under such conditions, LC_p was superior by 17.85 % over C_p and 12.78 % over L_p. Under conditions of no ^{15}N, superiority of the organic mixture was 4.6 and 6.0 % for C_t and L_t,, respectively.

Where nitrogen was given totally as organic, leucaena was superior over compost. In the time, leucaena–compost mixture; increases L_t and C_t over LC_t by 52.9 and 16.4 %, respectively. The main effect of combined with all-^{15}N gave greater yield over the no-N combined by average 61.8%.

Applying nitrogen in any of the forms and whether the dose was entirely mineral, or entirely organic or half mineral + half organic caused increases in N-uptake of lupines roots (Table 6). The main effect of organic sources resulted in LC > L > C. With no-N combination, all organic sources were similar. When combined with N, leucaena (Lp) and leucaena–compost (LCp) showed highest yields.

N combinations were considerably effective where either leucaena or its mixture with compost (Lp or LCp) were involved giving 20.4 and 27.0 % increases. The reverse occurred with compost which showed a 32.5 % decrease upon combination. This indicates an extremely positive enhancement to leucaena mineralization when an extra source of mineral N was added. In the case of compost, adding extra source of mineral N seemed to have enhanced net immobilization. The comparatively wider C/N ratio of composted may have contributed to immobilization [10]. Jung *et al* [6] noticed enhanced immobilization when compost was provided with soluble N.

Nitrogen derived from fertilizer

Regarding the amount of ^{15}N-uptake in shoots of lupine, results show that the amount of nitrogen derived from fertilizer (Ndff) ranged between 3 and 5 mg pot^{-1}. These amounts represent 6 to 7 % of total N uptake by shoots. The amount as well as the % Ndff were lower when N given solely as mineral ^{15}N, comparing to N given in half mineral and half organic. This indicates that the presence of organic material may have encouraged immobilization of fertilizer N (Table 7).

Considering the amounts of Ndff for the three organic treatments which received a combination of fertilizer ^{15}N + organic-N (i.e. treatments receiving 25 mg mineral ^{15}N + 25 mg organic-N), results show that the highest value was LC, and the lowest was L treatment. On the other hand, calculating the %Ndff, results show that the C treatment was the highest. It indicates that absorbed ^{15}N was translocated faster to shoots in treatment of compost (C), than in the other two treatments (since % Ndff regarding N uptake in roots was not the highest for this particular C treatment as compared with L or LC).

Ndfs which represents N derived from the soil, showed that the highest value was for L or C treatments along with the ^{15}N, giving % Ndff of about 18 and 17 %, respectively. Treatment of ^{15}N only gave a value of 14 % for shoot. Treatment receiving LC along with ^{15}N gave the lowest of 10 %.

These results indicate that the soil-N pool was enhanced by adding fertilizer which called priming effect [11]. El-kholi and Galal [12] and El-kholi *et al.* [13] reported enhancement of available N by adding organic amendments. Luxhøi *et al.* [14] using ^{15}N, showed that higher mineralization occurred when as little as 2 mg ^{15}N kg soil^{-1} ($^{15}NH_4^+$) in combination with 15 mg N kg soil^{-1}. They argued that in soils receiving 15 mg N kg soil^{-1}, the nitrogen pool was dominated by the $^{15}NH_4^+$, hence the effect of preferential consumption would be less obvious compared to soils where only 2 mg N kg soil^{-1} was applied.

Values for Ndfa (Table 7), reflected an effective response of lupines plants to *Rhizobium* inoculation, in particular which resulted in high percentage of N gained from air. It accounts for more than 80 % of total-N uptake by shoots of lupine. Addition of LC mixture combined with ^{15}N-fertilizer had enhanced the N_2 fixation and increased Ndfa by about 68.9 % over those recorded with treatment receiving ^{15}N-fertilizer alone. Addition of L combined with ^{15}N-fertilizer had also enhanced N_2 fixation, and increased Ndfa by about 28.1 %. Addition of C combined with ^{15}N gave an increase in Ndfa by 19.3 % over the ^{15}N without organic source. Therefore, leucaena caused a considerable increase in the portion of N derived from the air (biologically fixed-N) in relation to the total of N-uptake by plant. This indicates a greater enhancement of nodule formation and bacterial activity caused by leucaena. Ndfa was highest where ^{15}N was applied with LC or with no organic material accompanying it.

Table (7) Follow up the fate of reinforced ^{15}N-fertilizers of Lupines plant (rate 10 mg N kg^{-1} soil)

Added ^{15}N mg pot^{-1}	Ndff %	Ndff mg pot^{-1}	Ndfs%	Ndfs mg pot^{-1}	Ndfa%	Ndfa mg pot^{-1}
	Shoots					
50	5.87	3.03	13.90	7.18	80.23	41.49
25 + 25 L	6.55	4.60	18.16	12.81	75.29	53.16
25 + 25C	7.37	4.81	17.12	11.20	75.52	49.50
25+25(L+C)	6.10	5.08	9.82	8.17	84.08	70.09
	Roots					
50	8.65	2.01	91.35	21.15		
25 + 25 L	9.21	3.00	90.79	29.61		
25 + 25C	8.73	1.47	91.27	15.45		
25+25(L+C)	7.89	2.65	92.11	31.32		

Regarding the ^{15}N-uptake by roots of lupine, result show that Ndff ranged between 2 and 3 mg pot^{-1}. Calculating such amount as % Ndff (as percentage of the total amount of N uptake by roots) show that they represent about 8 and 9 %.

Considerable the amounts of Ndff for the three treatments which received a combination of fertilizer mineral ^{15}N+organic-material-N, results show the highest value being of the treatment of L, and the lowest for the C treatment. However, considering % Ndff results show that also the L treatment showed the highest value. It indicates that faster to roots in treatment of the leucaena, than in the other two treatments.

Recovery of ^{15}N by lupine plant

As presented in Table, (8), % recovery of fertilizer ^{15}N in all plant parts (shoots + roots) ranged between 10.08 % and 30.29 %. Therefore, between one-tenth to about one-third of fertilizer nitrogen was absorbed by lupine. The lowest occurred with application of mineral ^{15}N without mixing with organic manure; the highest occurred when mineral ^{15}N was mixed with leucaena or leucaena-compost mixture. This may indicate an active absorption of mineral ^{15}N where leucaena accompanied with ^{15}N mineral fertilizer. It may also indicates a possible high immobilization to applied mineral ^{15}N where no organic matter was present with it in the root environment.

Recovery in the shoots was greater than roots, particularly in treatment where compost accompanied with fertilizer ^{15}N. It indicates a high rate of translocation of fertilizer N from roots to shoots in presence of organic substances, particularly compost. Compost may have greater biological activity than leucaena. Fertilizer ^{15}N translocated to shoots was more than three-times than in roots in treatments where compost accompanied mineral fertilizer ^{15}N; in the case of treatment receiving fertilizer ^{15}N mixed with leucaena, shoots contained amount of fertilizer ^{15}N amounting to about one-and-half that which remained in roots. Therefore, it seems that compost enhanced translocation of fertilizer N from roots to shoots more than leucaena did. Ali [(15)], found that the lupine plants absorb low quantities of N from added mineral N. El-Kholi and Galal [(12)] reported that wheat was more dependent on fertilizer–N, especially with absence of bacterial inoculation (non–symbiotic relation), followed by those gained from soil-N pool.

Table (8) Percent of recovery fertilizer–^{15}N in soil under lupine and barley plants

Added ^{15}N mg pot^{-1}	% Recovery Lupine			% Recovery Barley
	Shoot (S)	Root (R)	Total (S +R)	Shoot
50	6.06	4.02	10.08	22.14
25 + 25 L	18.40	12.00	30.40	53.12
25 + 25 C	19.25	5.88	25.13	60.80
25 + 25 LC	20.32	10.60	30.92	82.16

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