Nitrogen Transfer from Pigeon Pea [*Cajanus Cajan* (L.) Misllp.] to Maize (*Zea mays* L.) In a Pigeon Pea /Maize Intercrop

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Abstract

In any land use system involving association of tree legume and non-legume cereal crops, it is important to know the quantity of fixed N transferred, and the possible time in which the transfer take place. Complete mixed root (CMR) method in a pot experiment was used to investigate the mechanism of N transferred in a pigeon pea/maize intercrop. The experiment was conducted during two rainy seasons. Results of the study showed that the quantity of N transferred by pigeon pea to maize through below-ground interaction progressively increases up to tasselling stage in both experimental trials with N concentration range of 0.31% to 0.60%, while N released through litter returns decreases from 1.05% to -0.12% in the first trial and 0.99% to -0.12% in the second trial during the growth cycle. The study also revealed that the period of release of N from pigeon pea through above-ground process occur at the early stage of growth (4 and 6WAP), while N transfer through below-ground process occur throughout the maize growth cycle. Generally, the results obtained in the study have proved that tree legumes can transfer considerable quantity of N within a short period in the growth cycle of companion annual crop.

Key words: Pigeon pea, maize, nitrogen transfer, above-ground process and below-ground process.

1. Introduction

Mixed culture (intercropping) of legumes and cereals is an old practice that dates back to ancient civilization, and it is a common practice in tropical agriculture as a solution to infertile soils and limited inorganic fertilizers. The potential benefit of intercropping systems is to maximize the use of resources such as space, light and nutrients (Willey, 1990, Morris and Garrity, 1993). Out of these three, soil fertility improvement through fixation and transfer of nutrients, (paticulaly nitrogen) from legume to companion crop is a major base for intercropping (Crew and people, 2004). Mixed culture between legume and cereal crop usually lead to complex series of inter and intra-specific interaction (Izaurraide *et. al*; 1992). Interactions can occur in the above or below-ground plant compartments when the component species are exploiting growth resources above and below-ground from the same location or at the same time (Ong *et. al,* 1996).

The advantage of intercropping, however, varies depending on several complex genetic and environmental factors (Ta and Farris, 1987). Using defferent legumes, Damaris (2007) reported the presence of inter-specific differences in dinitrogen fixation and excretion of nitrogen (N) and subsequent benefit by the companion crops. Biological nitrogen fixation and transfer by legume plant has received a lot of attention because it is a significant N source in agricultural ecosystems (Heichel,1987 and Izaurraide *et. al;* 1992). One of the common mechanisms of N transfer for the apparent benefit of the associated crop is by underground transfer, either through root and nodules decay or direct excretion of nitrogenous compounds (Ta and Farris, 1987; Ndakidem, 2006). Other mechanisms include stimulation of non symbiotic N fixation (Avery, 1991), N sparing effect and decomposition of fallen leaves (Fujita *et. al;* 1990; Chu *et. al;* 2004).

Although much work has been done on the estimation of rate of N fixation to the soil by crop legumes, there are few research works focusing on the contribution of tree legume roots to soil N. The basic problem of land users in agroforestry is that they lack the knowledge about the predicted or assured response of crops to fixed N. In any land use system involving association of nitrogen fixing and non-nitrogen fixing plants, it is important to know the quantity of N transferred and the possible time in which the transfer take place. The aim of this study therefore is to investigate the mechanism of release of, the quantity released or transferred, the time of transfer and the quantity that is subsequently taken up by the associated crop in an inter-cropping system using pigeon pea as legume and maize as companion crop.

2. Materials and Methods

2.1. Design of Experiment

This study was carried out at the Teaching and Research Farm of the Ekiti State University Ado-Ekiti, Nigeria (lat. 7^0 47'N, long. 5^0 13'E). Soil sample at 0 - 30 cm depth was collected from the fallow site of the farm. Physical and chemical properties of the soil were determined prior to the commencement of the experiment using standard methods. Thereafter, 75 medium-sized (55 cm x 48 cm x 48 cm) polythene bags were filled with 20 kg soil. Five (5) different experimental treatment including control were imposed as follows: (1). Pigeon pea intercropped with maize (below-ground interaction) (Treatment A); (2). Pigeon pea intercropped with maize plus leaf biomass of pigeon pea (below-ground and above-ground interaction) (Treatment B); (3). Maize crop plus leaf biomass of pigeon pea (above-ground interaction) (Treatment C); (4). Maize crop only (no interaction) (Treatment D) and (5). Pigeon pea plant only (Treatment E). Completely Randomized Design (CRD) was used for the experiment each at three replicates and repeated five times to allow for periodic harvesting.

2.2. Procedure of the experiment

Two seeds of pigeon pea were sown into each of the required polythene bags. Two weeks after sowing, the germinated pigeon pea seedlings were thinned to one seedling per bag and allowed to grow for six weeks for proper establishment. Then two viable grains of maize (*Z. mays L*) were sown in each of the polythene bags including those containing pigeon pea plants at 10 cm away from the base of the pigeon pea plant. Ten days after sowing, maize plants were also thinned to one stand per bag. Periodically as required, the pigeon pea plants were pruned as necessary to prevent shading of the intercropped maize. For treatment A, the pruning and litter were periodically removed from the pot. For treatments B and C, 60 g of dried and crushed pigeon pea leaf biomass was simultaneously applied as mulch on the same day of sowing maize. The experiment was conducted over two raining seasons. At fourth week of the planting date of maize (4WAP), one stand per treatment was uprooted and separated into leaf, stem and root. The roots of both plants were then washed free of soil with water. soil samples from each bag were collected and air-dried, while maize and pigeon pea component parts were air dried. N concentration for each sample was determined using Kjeldhal method (AOAC, 1990). The procedure was repeated at 6, 8 and 10WAP. N transfer by pigeon pea to maize and the proportion of the transferred N in maize and concentration of N in maize were estimated by differences following the procedures of Sanginga *et. al* (1990) and Kounosuke *et. al* (1990).

2.3. Statistical Analysis

Data collected during the experiment were subjected to one way Analysis of Variance using Statistical Analysis System (SAS) (2000) package at 5% level of significance to determine differences in the treatment effect. Where significant differences occurred in the treatment means, the means were separated using Duncan's New Multiple Range Test.

3. Results

3.1. Mechanism and quantity of nitrogen transfer from pigeon pea to maize

The result on mechanism of N transfer during the first and second experimental trials conducted in 2009 and 2010, shows that there was a transfer of N from pigeon pea to maize through root to root excretion (below-ground process), through litter return (above-ground process) and through below and above-ground interactions. At 4 weeks after planting (WAP) in the first experimental trial, quantity of N transferred by pigeon pea to maize through root to root excretion was 0.31 %. During this period, N released from leaf biomass return was 1.05 % while above and below-ground interaction processes have the least N transfer value of 0.07 %.

At 6WAP, N transfer to maize through root to root excretion was 0.59 %, while N released from leaf biomass return was 1.02 %, while the least N transfer value (0.04 %) was equaly obtained for above and below-ground interaction processes. At 8 and 10WAP, there was a deficit in N contribution through above-ground process from litter return (– 0.22% and – 0.12 %) respectively. However, during this growth period 0.60 % and 0.37 % of N were transferred respectively from pigeon pea to maize via below-ground process (Table 1a). Transfer due to above-ground and below-ground interaction processes was negative at 8WAP (- 0.28 %) and at 10WAP the value increased to 0.40%. The same trend of result obtained during the first experimental trial with respect to N transfer and N released were observed during the second experimental trial (Table 1b). At the early stages of growth (4 and 6WAP), N transfer by pigeon pea via below-ground process were 0.39 % and 0.53 % respectively, while N released from litter return were 0.99 % and 0.90 % respectively. During the same period N transfer due to interaction of above and below-ground processes were 0.15 % and 0.14 % respectively. At maturity (8 and 10WAP), 0.60 % and 0.09 % of N were transferred from pigeon pea to maize via below-ground process, while N released through litter return from pigeon pea leaf biomass was negative (- 0.08 % and - 0.12 %) respectively.

3.2. Proportion of transferred nitrogen in maize

The proportion of transferred N in maize intercrop with pigeon pea plant (below-ground) consistently increases from 34.44 % to 42.25 % in the first trial and 43.82 % to 44.77 % in the second trial at 4-8WAP of the maize growth cycle. The proportion of released N in maize with application of leaf biomass (above-ground), decreases from 62.87% at 4WAP to -13.33% at 10WAP. While the proportion of transferred N in maize due to below and above-ground interaction consistently decreases up to 8WAP and then increases at 10WAP in the first trial.The same trend of N transfer was obtained for below and above-ground interaction in the second trial (Table 2).

3.3. Pattern of nitrogen concentration in maize during growth cycle

N concentration in maize crop shows a steady increase for below-ground treatments up to 8WAP in both the first and second experimental trial. The concentration then decreases to 1.39 % and 1.13% respectively at 10WAP. At 8WAP, N concentration increases at the early growth stage (4 and 6WAP) in maize intercropped with pigeon pea plus leaf biomass (below and above-ground interaction) and maize with the application of pigeon pea leaf biomass (above-ground treatment) . At 8WAP, N concentration decreases and at 10WAP the concentration increases again. (Table 3). The result further shows that in both experimental trials, N concentration was significantly higher ($P > 0.05$) at 4 and 6WAP in maize with application of leaf biomass (above-ground process). At 8WAP, N concentration was significantly higher ($P > 0.05$) in maize intercropped with pigeon pea (below-ground process), while there was no significant difference in maize N concentration for all the treatments at 10WAP.

4. Discussion

This study revealed that there was a transfer of N from pigeon pea to maize by intercropping both crops through root to root interaction (below-ground process), through litter return (above-ground process) and through the combination of both below-ground and above-ground processes. The steady increase in the quantity of N transferred from pigeon pea plant to maize observed in this study (Tables 1) is a clear evidence of the advantage of intercropping in relation to N flux in cereal crop/legume intercropping. Since there was no external input either in form of organic or inorganic fertilizer to the soil in pigeon pea/maize treatment, N transferred in this treatment could only have resulted from below ground process. This process could be by direct transfer via mycorrhizal connections between the two plants (Johansen and Jensen, 1996) or by rhizo-deposition (root to root excretion) (Purnamawati and Schmidtke, 2003). It could have also been via root and nodular tissue decay (Ta and Farris, 1987). The evidence that legume fix large quantity of N especially in a nitrogen deficient soil and transfer substantial amount of it to companion crop had earlier been reported by Ofori and Stern, (1987). The steady increase in the proportion of N transferred (Table 2) in maize intercrop with pigeon pea in this study might have been enhanced by mycorrhizal interaction in the roots between the two plants. This finding corroborates the report by Rovira *et. al;* (1979) who noted that hyphae network association with legume (Berseem) root is capable of infecting an associated apple tree, thereby facilitating the transfer and uptake of nutrient. The observed increase in the proportion of N transferred in maize intercropped with pigeon pea (below-ground) up to tasselling stage (Table 2), is a further proof of the importance of intercropping in soil nutrient accumulation and plant nutrition improvement in agroforestry systems.

This assertion agrees with the report by Egbe *et. al*; (2007) on a pigeon pea/maize intercrop experiment. The highest proportion of released N in maize with leaf biomass application at the early stage of growth (Table 2) may be attributed to synchrony between the release of N from the decomposed leaf biomass of pigeon pea and the subsequent uptake of N by maize at that stage of growth cycle. This assertion agrees with earlier reports (Haggar *et. al* 1993 and Oyun, 2001) who independently indicated that higher concentration of mineralized N released by decomposing litter and N uptake by maize occur during the first 6 weeks of maize growth. Chu *et. al;* (2004) in a similar study reported that cowpea litter contributes 16 – 28 % N to N uptake of maize at early growth stage in a field trial on a nitrogen deficient soil. One major factor that could have been responsible for this increase in N absorption by maize at this stage of growth cycle is the rapid decomposition of pigeon pea leaf biomass (high quality litter) to release mineralized N. The released mineralized N potentially increases soil N concentration thereby making sufficient N available for uptake by maize, since there was no competition for maize plant as regards N uptake in this treatment. Similar result with respect to litter N-mineralization and N-absorption had been reported by Patra *et. al*; (1990) and Oyun (2001). The observed negative value in the quantity of N released from leaf biomass at 8 and 10WAP in this study may be due to immobilization of mineralized N at that period. This can be explained by the fact that this is a period of high microbial population.

These microbial organisms (bacterial) which require nutrients to grow usually consume the decomposing litter and convert the nutrients there to microbial biomass N, thereby depleting the soil of mineral N. At this period N is locked up in their system and become unavailable for plant uptake. This observation confirmed earlier report by Oyun (2001) who noted that this period of negative N uptake by maize coincides with the period of high microbial population in decomposing litter of *Gliricidia sepium*. Also negative N value at this period could be due to losses from volatilization and leaching in which case the mineralized N drained through the polythene bag down the soil beyond the reach of the plant. Low quantity of N transferred in below and above-ground interaction processes in this study is probably due to competition between maize and pigeon pea plant for mineralized N. Since pigeon pea is a higher demander of N than maize at the early stage of growth (Ofori and Stern, 1986) its companionship could inhibit the N uptake of maize plant. Also the fact that pigeon pea would not fix N when grown in a N enriched soil (Sanginga *et.al;* 1992), could make it to depend mainly on the mineralized N from the litter decay, thereby depriving the maize access to sufficient N uptake rather than transferring N to maize. The highest value of N concentration obtained in maize with application of leaf biomass (above-ground process) at the early stage of growth (4 and 6WAP) in this study, was due to the improvement in the soil N content by the decomposed pigeon pea leaf biomass (Mafongoya *et. al*; 1998 and Oke, 2001). High quality attribute coupled with placement pattern, just below the surface, enhanced quick decomposition and mineralization of the litter to release N (Oyun, 2001; Jama and Nair, 1996).

Since maize require large quantity of N at the early growth stage for vegetative development, a situation occurred whereby there was a synchrony between N release and N uptake which further enhanced high level of N concentration in maize at this growth stage. The decline in N concentration level of maize with application of leaf biomass (above-ground process) at maturity (8 and 10WAP) might be due to low level of available N as a result of volatilization, leaching and immobilization. Observed low N concentration value in maize intercropped with pigeon pea plus leaf biomass (above and below-ground interaction) at 4 to 8WAP in this study irrespective of the addition of leaf biomass may be due to competitive interaction between the two plants for mineralized N. Maize intercropped with pigeon pea in this study was better nourished in N requirement from early development up to the tasselling stage (Table 3). This was due to N sparring effect by pigeon pea (Ta and Farris, 1987) and atmospheric N fixation by pigeon pea through mycorrhizal association in root nodules which also stimulate the release of soil mineral N (Zuo *et.* al*;* 2003).

5. Conclusion

Results from this study has shown that transfer of N from legume shrub (pigeon pea) to companion annual crop occur through below-ground process (via root to root excretion), through above-ground process (via litter returns) and through interaction of both above –ground and below-ground processes. The study has further revealed synchrony between N release by pigeon pea leaf biomass and N uptake of maize at the early growth stage (4 and 6WAP). Result on the proportion of N transfer in maize had shown that pigeon pea plant contributes up to 44.7 % of N nutrition of maize via below-ground process, while contribution via above-ground process was 66.44 %. Conclusively this study has proved that tree/shrub legumes can fix and transfer considerable quantity of N within a short period in the growth cycle of companion annual crop.

Table 1: Mechanism and quantity of N transfer from pigeon pea to maize

First year trial

Mechanism	Quantity transfer (%) WAP			
	4	6	8	10
Below-ground (root to root excretion)	0.31	0.59	0.60	0.37
Below and above-ground interaction process	0.07	0.04	-0.28	0.40
Above-ground (leaf biomass returns)	1.05	1.02	-0.22	-0.12

Second year trial

Mechanism	Quantity transfer (%) WAP			
	4	6	8	10
Below-ground (root to root excretion)	0.39	0.53	0.60	0.09
Below and above-ground interaction process	0.15	0.14	-0.16	0.02
Above-ground (leaf biomass returns)	0.99	0.90	-0.08	-0.12

Table 2: Proportion of the transferred and released N in maize (%)
First year trial

Treatments	Weeks after planting			
	4	6	8	10
Pigeon pea + maize	34.44	41.84	42.25	26.61
Pigeon pea + maize + leaf biomass	10.14	4.65	-52.83	4.23
Maize + pigeon pea leaf biomass	62.87	55.43	-37.28	-13.33

Second year trial

Treatments	Weeks after planting			
	4	6	8	10
Pigeon pea + maize	43.82	43.80	44.77	7.96
Pigeon pea + maize + leaf biomass	23.07	17.07	-27.59	-1.89
Maize + pigeon pea leaf biomass	66.44	56.60	-12.12	-11.54

Table 3: Nitrogen concentration (%) in maize during growth cycle
First year trial

Treatments	Weeks after planting			
	4	6	8	10
Pigeon pea + maize	0.90^{b}	1.41^{b}	1.41^{a}	1.39^{a}
Pigeon pea + maize + leaf biomass	0.69^{bc}	0.86^{c}	0.53^{b}	1.42^{a}
Maize + pigeon pea leaf biomass	1.67^{a}	1.84^{a}	0.59^{b}	0.90^{a}
Maize only	0.62^{c}	0.80^{c}	0.81^{b}	1.02^{a}

Second year trial

Treatments	Weeks after planting			
	4	6	8	10
Pigeon pea + maize	0.89^{b}	1.21^{b}	1.34^{a}	1.13^{a}
Pigeon pea + maize + leaf biomass	0.65^{bc}	0.82^{b}	0.58^{b}	1.06^{a}
Maize + pigeon pea leaf biomass	1.49^{a}	1.59^{a}	0.66^{b}	0.92^{a}
Maize only	0.50^{c}	0.68^{c}	0.74^{b}	1.04^{a}

Mean with the same superscripts in the same column are not significantly different ($P > 0.05$)

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