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NITROGEN ACCUMULATION, GROWTH AND YIELD OF MAIZE IN PIGEON PEA/MAIZE INTERCROP

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Abstract

Complete mixed root (CMR) method in a pot experiment was carried out to estimate N accumulation, growth and yield of maize in pigeon pea/maize intercrop. The experiment was conducted during two rainy seasons. N accumulated by maize through below-ground interaction increased steadily with N concentration range of 0.90% at 4WAP to 1.41% at 8WAP in the first trial, while in the second trial N accumulation over the same period ranged between 0.89% and 1.34%. N accumulation by maize through litter application (above-ground process) was significantly ($p< 0.05$) higher at the early growth stage for both experimental trials. Significant ($p< 0.05$) higher growth [height (151.36 cm), diameter (2.25 cm)] and grain yield (111.39 g) was obtained for maize with litter application. Generally, the study has established that intercropping tree legumes with cereal crop consistently and considerably increases N accumulation and yield of companion annual crop.

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

1. Introduction

The role of nitrogen in agroecosystems has become considerably scrutinized through research driven by the well documented environmental and economic concerns associated with high N losses. The performance of trees and crops in a mixture depends upon their relative ability to tap the pool resources of light, water and mineral nutrients and also on their responses to such optimal level of these resources (Connor, 1983). Association between a non-legume and a legume species is generally considered beneficial, because it is assumed that the nitrogen nutrition of non-legume plant is improved when grown in association with legume (Hamel *et al* 1991). However, nutrient use in intercropping system depends on both the time of nutrient accumulation during the growth cycle and the rate at which nutrients are utilized and converted to biomass by the associated non-legume crop (Mafongoya *et. al;* 1998).

The general interest shown in mixed cropping of cereals and legumes stems mainly from the speculated advantages of intercropping systems such as greater dry matter production, improvement of soil fertility through the addition of nitrogen by fixation and/or excretion from the root of legume component, soil moisture conservation by cover crops and multiple products from a piece of land (Fujita *et al* 1990). In the tropics amelioration of low soil fertility through application of inorganic and organic fertilizers is a common practice. However, the supply of inorganic fertilizer is limited and where available, it is costly. The only alternative way out of this problem by small land holder agroforest farmers, is the substitution of costly inorganic farming with low cost organic farming through intercropping of cereal and legume crops and application of mulch. In this practice, it is necessary for farmers to know the release and uptake functions of the limiting nutrients in order to synchronize the periods of maximum supply from the legume and decomposing mulch with those of maximum demand of the companion crop.

Legumes are very important both ecologically and agriculturally because they are responsible for a substantial part of the global flux of nitrogen from atmospheric nitrogen to fixed form (Patriarca *et. al;* 2002). Review of current literature revealed that few research works on intercropping is specifically addressing the importance of leguminous woody species, on the basis of potential amount of N contribution to companion crop and that which is subsequently taken up by the associated non-legume crop. The aim of this study therefore is to evaluate N accumulation by the companion non-legume cereal annual crop for biomass production and grain yield in intercropping system, using pigeon pea as shrub legume and maize as companion non-legume cereal 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 plus leaf biomass of pigeon pea (above-ground interaction) (Treatment C);
(4). Maize 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 (*Zea. 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 equally air dried. N concentration for each sample was determined using Kjeldhal method (AOAC, 1990). The procedure was repeated at 6, 8 and 10WAP. Concentration of N in maize and the proportion of the transferred N in maize were estimated by differences following the procedures of Sanginga *et. al* (1990) and Kounosuke *et. al* (1990). At maturity, maize cob was harvested. The cob was shelled to separate the rachis and grains, the grains were oven dried to a constant weight for about 10 minutes to determine the grain weight.

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. Pattern of nitrogen accumulation in maize during growth cycle

N accumulation in maize steadily increases at the early stage of growth cycle (4-6WAP) for all the treatments in both experimental trials (Table 1). At 8WAP, N concentration value declined to 0.53 %, 0.59 % and 0.81% respectively in maize intercropped with pigeon pea plus leaf biomass (below and above-ground interaction); maize with the application of pigeon pea leaf biomass (above-ground process) and mono-crop maize. At 10WAP the accumulation increases again for the three treatments. In the second experimental trial, N accumulation in maize followed the same trend as obtained in the first trial. The result further shows that in both experimental trials, N accumulation was significantly higher ($p< 0.05$) at 4 and 6WAP in maize with application of leaf biomass (above-ground process). At 8WAP, N accumulation was significantly higher ($p< 0.05$) in maize intercropped with pigeon pea (below-ground process), while there were no significant difference in maize N concentration in all the treatments at 10WAP.

Table 1: 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}	0.82^{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 ($P < 0.05$)

3.2. Proportion of transferred N in maize

Proportion of transferred N in maize intercropped with pigeon pea (below-ground) increases from 34.44 % to 42.25 % in the first 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% to -37.28% at 4-8WAP of the maize growth cycle in the first trial. While the transferred N in maize due to below and above-ground interaction decreased during the same growth period. The same trend of result was obtained for all the treatments in the second trial (Table 2).

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

3.3 Growth and yield of maize as influenced by above-ground and below-ground processes

Maize height in all the treatments gradually increases throughout the growth cycle in both experimental trials. Maize with application of leaf biomass (above-ground process) had the highest height value throughout the growth cycle in both experimental trials (Table 3). At 4WAP in both experimental trials, maize intercropped with pigeon pea (below-ground process) had the least height values, while the least height values was obtained for mono-crop maize at 6, 8 and 10WAP. Maize stem diameter gradually and consistently increases in all the treatments. Maize with application of leaf biomass (above-ground process) had significantly ($p<0.05$) higher stem diameter than all other treatments throughout the growth cycle. At 4WAP, maize intercropped with pigeon pea had the least stem diameter, while at 6 and 8WAP stem diameter was least for mono-crop maize (Table 4).

Dry matter yield increases throughout the growth cycle for all the treatments in both trials. Dry matter yield in maize plant with application of leaf biomass was significantly higher ($p< 0.05$) than in the other treatments. At the early growth stage (4-6WAP), dry matter yield was significantly lower in maize intercropped with pigeon pea (below-ground process), while at maturity (8-10WAP) dry matter yield was least in mono-crop maize (Table 5). Maize yield in this study reveals that maize with application of leaf biomass (above-ground process), had the highest value for cob weight, cob diameter and grain weight in both the first and second experimental trials. However, the value for cob length in all the treatments are not significantly different ($p<0.05$) (Table 6).

Table 3: Maize height (cm) during the growth cycle

First year trial

Treatments	Weeks after planting			
	4	**6**	**8**	**10**
Pigeon pea + maize	10.67^{d}	30.33^{c}	51.06^{c}	82.40^{c}
Pigeon pea+ maize + leaf biomass	27.56^{b}	48.76^{b}	79.20^{b}	103.00^{b}
Maize + pigeon pea leaf biomass	30.36^{a}	56.76^{a}	98.63^{a}	137.60^{a}
Maize only	17.93^{c}	28.50^{d}	47.73^{d}	57.00^{d}

Second year trial

Treatments	Weeks after planting			
	4	**6**	**8**	**10**
Pigeon pea + maize	10.86^{b}	26.10^{c}	47.27^{c}	86.40^{c}
Pigeon pea+ maize + leaf biomass	16.13^{b}	48.73^{b}	87.60^{b}	136.60^{b}
Maize + pigeon pea leaf biomass	30.73^{a}	60.00^{a}	138.73^{a}	151.36^{a}
Maize only	14.05^{b}	21.20^{d}	34.40^{d}	73.43^{d}

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

Table 4: Maize diameter (cm) during the growth cycle

First year trial

Treatments	Weeks after planting			
	4	**6**	**8**	**10**
Pigeon pea + maize	0.41^{c}	1.14^{b}	1.33^{c}	1.44^{c}
Pigeon pea+ maize + leaf biomass	0.45^{b}	1.47^{a}	1.66^{b}	1.86^{b}
Maize + pigeon pea leaf biomass	0.48^{a}	1.50^{a}	2.11^{a}	2.25^{a}
Maize only	0.45^{b}	0.86^{c}	1.18^{d}	1.47^{c}

Second year trial

Treatments	Weeks after planting			
	4	**6**	**8**	**10**
Pigeon pea + maize	0.27^{b}	0.87^{b}	1.24^{b}	1.30^{b}
Pigeon pea+ maize + leaf biomass	0.36^{b}	1.38^{b}	1.61^{ab}	1.45^{b}
Maize + pigeon pea leaf biomass	0.80^{a}	2.51^{a}	2.20^{a}	2.04^{a}
Maize only	0.48^{ab}	1.76^{ab}	1.89^{ab}	1.57^{b}

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

Table 5: Dry matter yield of maize plant (g) during the growth cycle

First year trial

Treatments	Weeks after planting			
	4	6	8	10
Pigeon pea + maize	9.5d	16.7d	46.2b	55.5b
Pigeon pea+ maize + pigeon pea leaf biomass	13.4b	26.0b	32.6c	46.7c
Maize + pigeon pea leaf biomass	24.3a	58.3a	79.49a	86.0a
Maize only	12.6c	21.9c	30.3d	38.2d

Second year trial

Treatments	Weeks after planting			
	4	6	8	10
Pigeon pea + maize	7.0^{c}	14.2^{d}	40.5^{b}	52.3^{b}
Pigeon pea+ maize + pigeon pea leaf biomass	10.7^{b}	20.5^{b}	42.4^{b}	48.1^{c}
Maize + pigeon pea leaf biomass	15.6^{a}	44.3^{a}	70.6^{a}	80.4^{a}
Maize only	7.1^{c}	17.0^{c}	32.3^{c}	35.0^{d}

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

Table 6: Maize yield at harvest

First year trial

Treatments	**Cob Weight (g)**	**Grain Weight (g)**	**Cob Length (cm)**	**Cob Diameter (cm)**
Pigeon pea + maize	101.89^{b}	80.16^{ab}	13.00^{a}	3.89^{a}
Pigeon pea + maize + leaf biomass	69.19^{bc}	56.45^{bc}	9.90^{ab}	3.59^{a}
Maize + pigeon pea leaf biomass	156.32^{a}	111.39^{a}	12.00^{ab}	3.93^{a}
Maize only	49.60^{c}	38.95^{c}	8.20^{b}	2.83^{b}

Second year trial

Treatments	Cob Weight (g)	Grain Weight (g)	Cob Length (cm)	Cob Diameter (cm)
Pigeon pea + maize	81.99[a]	68.91[ab]	22.82[a]	3.59[a]
Pigeon pea + maize + leaf biomass	66.85[a]	57.70[ab]	14.17[a]	3.78[a]
Maize + pigeon pea leaf biomass	95.86[a]	79.62[a]	20.23[a]	3.86[a]
Maize only	53.26[a]	35.42[b]	13.00[a]	2.52[a]

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

4. Discussion

The highest value of N accumulation obtained in maize with application of leaf biomass (above-ground process) at the early stage of growth (4 and 6WAP) in this study, could be due to the improvement in the soil N content by the addition of pigeon pea leaf biomass. Mafongoya *et. al*; 1998 and Oke, 2001 reported that pigeon pea leaf biomass is a high quality litter which decompose very fast to release nutrients to the soil. This attribute coupled with placement pattern, just below the surface, could also enhanced quick decomposition and mineralization of the litter to release N (Jama and Nair, 1996; Oyun, 2001). 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 accumulation in maize at this growth stage. The decline in N accumulation in 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 immobilization, volatilization and leaching at this period.

Observed lower N accumulation in maize intercropped with pigeon pea plus leaf biomass (above-ground and below-ground processes) at 4 to 8WAP in this study as compared to N accumulation in maize intercropped with pigeon (below-ground process) irrespective of the addition of leaf biomass may be due to competitive interaction between the two plant for mineralized N. In the case of below-ground process, soil mineral N could have been spared by pigeon pea for uptake by maize (Ta and Farris, 1987). In addition to this sparring effect by pigeon pea, atmospheric N fixation by pigeon pea through the mycorrhizal association in root nodules could also stimulate the release of soil mineral N (Zuo *et.* al*;* 2003). These two processes could cause an increase in the quantity of available N in the soil; thereby improving the N uptake of maize in pigeon pea maize intercrop. This observation suggests that maize intercropped with pigeon pea in this study was better nourished in N requirement for early development up to the tasselling stage than maize intercropped with pigeon pea plus leaf biomass.

The highest N accumulation observed in pigeon pea intercropped with maize (below-ground) over that of the value obtained in pigeon intercropped with maize plus leaf biomass (above and below-ground process) throughout the growth cycle in this study (Table 6), in spite of the N enrichment by leaf biomass is an indication that pigeon pea is highly efficient in converting biologically fixed nitrogen to biomass nitrogen in an intercropping system. This observation suggests that when pigeon pea is intercropped with other crop in N stressed condition, it prefer to derive its N requirement mainly from atmospheric N fixation by sparring soil mineral N for absorption by companion crop. Martin *et al* (1991) reported similar observation in soybean /maize intercropping studies.

The rapid vegetative development at the early stage of growth exhibited by maize with application of leaf biomass (above-ground) throughout the growth cycle in this study, could be attributed to better nourishment from the soil abundant mineralized N and other plant nutrients from decomposed pigeon pea leaf biomass (Kannayan *et. al;* 1988). The rapid decomposition and mineralization of pigeon pea leaf biomass to release N coincide with the period of optimum nutrient absorption for vigorous vegetative development in maize plant. In addition to the release of N and other nutrients, the decomposition of pigeon pea leaf biomass at this stage could also perform other functions. Palm *et. al;* (1997) and Oke (2001) reported that such functions may include the supplying of energy source through nutrients availability to soil organism thereby enhancing nutrient cycling in the soil, reduction in phosphorus (P) sorption capacity of the soil and stimulation of root growth.

The relatively slow growth rate observed for maize intercrop with pigeon pea (below-ground) as compared to mono-crop maize at 4WAP might be attributed to competition for soil nutrient between maize and pigeon pea at that growth stage. The significant improvement observed in growth of maize intercropped with pigeon pea over that of mono-crop maize at 6 to 10WAP despite the minimal shading effect of pigeon pea on maize, could be due to improvement in the nutrient status of the soil through N fixation by pigeon pea plant, while N status of the mono-crop maize soil continued to deplete. Intercropping pigeon pea with maize do not have any negative effect on the growth of maize as maize in intercropping treatments performed better in terms of physiological growth than mono-crop maize. This claim is in agreement with the findings of Rafey and Parasade (1992) and Thakur and Sharma (1988) who reported that maize intercropped with pigeon pea had higher physiological growth than mono- crop maize.

The apparent and significant higher dry matter yield obtained in maize with application of leaf biomass (above-ground process) compared to the values obtained for maize plant in other treatments in this study, might be due to better nourishment derived from the soil as a result of enrichment with pigeon pea leaf biomass which greatly improves soil nutrient status. The applied pigeon pea leaf biomass in this treatment decomposed very fast and mineralized within the first 6 weeks to release N into the soil which invariably was made readily available for maize uptake. The consequence of this was the profuse accumulation of dry matter since this was the period of rapid vegetative development in maize. Similar performance have been reported in the case of dry matter yield for maize grown in soil improved with legume litter compared with the maize in plot without addition (Nizam and Virgilio 1989; Dapaah *et al* 2003 and Ndakidem 2006). The trend of dry matter yield in maize intercropped with pigeon pea compared with mono-crop maize in this study is similar to the observation of Lingaraju *et al* (2008) who reported that cereals intercropped with legume produce higher dry matter yield than when they are grown alone.

The significant and higher grain yield obtained in maize with application of leaf biomass in this study over maize in other treatments may be attributed to better nourishment as influenced by the sufficient nutrient supply to maize at the early growth stage when it is most needed for rapid vegetative development Similar performance had been reported in the case of grain yield of maize grown in soil improved with legume litter (Myers et. *al;* 1997). In addition to improvement in soil nutrient status, higher grain yield obtained in maize intercropped with pigeon pea (below-ground process) and in maize intercropped with pigeon pea plus leaf biomass (above and below-ground process) over that of mono-crop maize in this study could also be attributed to soil moisture conservation as influenced by legume cover. This assertion agrees with earlier report by (Tian *et. al;* 1993) that maize intercropped with legume gave better yield than sole maize in moisture stressed condition. In the same vain observed higher grain weight in maize intercropped with pigeon pea compared to the grain weight of mono-crop maize in this study might also be as a result of improve soil nutrient through biological N fixation. The long-term N uptake advantage exhibited by maize in pigeon pea/maize intercrop (below-ground process) in this study probably explained the higher value obtained for all the yield variables in this treatment. This assertion is a confirmation of earlier report by Madar (2001), Rathod *et al* (2004) and Lingaraju *et. al;* (2008), who in their separate studies reported that mixture of cereals and legumes produce higher dry matter and grain yield in cereals than when the cereals are grown alone.

5. Conclusion

Result from this study showed a synchrony between N release by pigeon pea and N uptake and accumulation by maize at the early growth stage (4 and 6WAP). Also the study further revealed that there is better physiological growth and grain yield for maize intercropped with pigeon pea plant (below-ground) and maize with application of leaf biomass (above-ground) than mono-crop maize with no addition.

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