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CONTRIBUTION OF PIGEON PEA ROOTS TO NITROGEN AND PHOSPHORUS YIELDS IN THE PIGEON PEA-GROUNDNUT INTERCROP SYSTEM

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ABSTRACT

A study aimed at the assessment of the contribution of pigeon pea roots to N yield for the pigeon pea was conducted at Chitedze Agricultural Research Station (S 13^0 59' 23.2", E033^0 38' 36.8"), Malawi in the 2012/2013 cropping season. Ten treatments, replicated three times were laid in a randomized complete block design. Two pigeon pea varieties, long (ICEAP 04000) and medium duration (ICEAP 00557) and groundnut (CG 7) were grown as monocultures and intercrops. The intercrops involved planting either of the pigeon pea varieties with groundnut. Some of the plots were treated with triple super phosphate (TSP) at the rate of 25 kg P ha^{-1}. Analysis of soil samples collected in all treatment plots indicate that the soil had low fertility, having; low organic carbon (1.4 %), low cation exchange capacity (CEC) (NH_4OAc) (3.5-3.6 cmol (+) kg^{-1} soil) and low N (0.12%), while plant available phosphorus (Mehlich 3) was marginally adequate both in the top and sub soil (μ=21.5 mg P kg^{-1} and 22.1 mg P kg^{-1}). Assessment of pigeon pea root biomass indicated a mean yield range of 507-605 kg ha^{-1}. Phosphorus yields in the roots ranged from 0.3 kg ha^{-1} to 0.5 kg ha^{-1}

while N yield of 5.7 kg N ha^{-1} to 7.7 kg N ha^{-1}, a modest contribution to the soil N pool. Though modest the contribution by roots of N to the soil cannot be overlooked since the nutrient even after immobilization, a temporally state, largely is available for uptake by succeeding crops in a rotation system as it does not get complexed in the soil as is the case with phosphorus.

Keywords: Biomass, groundnut, Intercrop, maize, nitrogen, pigeon pea and roots

INTRODUCTION

The role of legumes in soil fertility rejuvenation is globally reckoned and remains a vital link towards sustainable agricultural production. The role played by legumes, nitrogen (N) fixation and high quality biomass production are chorused as the main reasons why legumes hold a key to sustainable agriculture. Other equally important unique traits of legumes have also been spelt out and these include; the capacity to excrete root compounds that solubilizes complexed phosphorus (P) that otherwise remain unavailable (Drinkwater and Snapp, 2007). For example, the roots of pigeon pea (*Cajanus cajan*), produce an exudate (piscidic acid-$C_{11}H_{12}O_7$) which releases P from the Fe-P complexes through solubilization, thereby increasing available P (Ae *et al.*, 1990). The deep penetrating and laterally spreading root system confers drought tolerance through optimal use of soil moisture (Sharma, 2009). Furthermore, the deep roots absorb nutrients from deeper soil horizons, thereby recycling nutrients translocated to deep horizons (Masson *et al.*, 1986). On the otherhand, the highly prized annual edible legume, groundnut (*Arachis hypogaea*), possess a unique ability of utilizing soil nutrients that relatively are unavailable to other crops (Ikisan, 2000). The crop is also billed as very effective in extracting nutrients from soils of low nutrient supply, possibly as a result of the mycorrhizal association between roots and soil fungi or because of phosphobacteria found in the rhizosphere (Ikisan, 2000). Mycorrhizal association between roots and soil fungi, effectively extends roots beyond the nutrient depletion zone that is found around roots and increases the surface area thereby enabling plant roots to exploit a greater volume of undepleted soil and increase the specific surface area for P absorption (Lambers, 2008; Lambers *et al.*, 2011). Plants whose roots form mycorrhizal with soil fungi absorb more nutrients, particularly P even at low concentration from the soil solution compared with other plants that do not form such associations (Lynch and Brown 2001). Zhu *et al.* (2010) reported that mycorrhizal hyphae have a higher affinity for P than roots. Over and above the aforementioned, around the hyphae, the P concentration gradient is limited, thus there exists a minimal depletion zone (Barber, 1984). Principally, this is because the radius of hyphae (0.005 mm) is much smaller than that of roots plus root hairs (0.15 mm) (Rai *et al.*, 2013). This results into perpetually higher P concentration in soil solution around the hyphae than in the P depletion

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zone around roots (Rai *et al.*, 2013). Consequencially, the hyphae absorbs more P under conditions of low soil P even in the absence of a higher affinity for the nutrient (Rai *et al.*, 2013). It has been documented that mycorrhiza releases organic anions such as citrate, malate and oxalate, which can occupy P ($H_2PO_4^-$, HPO_4^{2-} and PO_4^{3-}) sorption sites thereby enhancing availability of P into the soil for plant uptake (Richardson *et al.*, 2011).

A less emphasized dimension on the role of legumes in recharging soil fertility is their contribution to the soil nutrient pool by decayed roots especially for leguminous plants like pigeon pea (Guretzky *et al.*, 2004; Cherr *et al.*, 2006). Crops and trees root residues contribute substancially to nutrient dynamics and pools and carbon turnover in agricultural ecosystems (Egbe *et al.*, 2013). Roots of plants also accord pathways for channeling of carbon and energy from the canopies to the soil (Egbe *et al.*, 2013). Implicitly therefore, root production and turnover directly impact the biogeochemical cycles of carbon and nutrients in terrestrial ecosystems (McGroddy *et al.*, 2004; Majdi *et al.*, 2005; Espeleta and Clark, 2007). Decomposition of root biomass and subsequent mineralization of the organically bound nutrients from the roots might have a positive influence on the growth of succeeding crops in rotational cropping systems such as the pigeon pea-groundnut intercrop maize rotational cropping system. Nnadi and Haque, (1986), reported that under intercropping, legume roots can contribute between 5 and 15 kg N ha^{-1} to soil N pool. In a study conducted by Phiri *et al.*, (2013b), the root component and the accompaning nutrient yields for two pigeon pea varieties used in the study were not assessed, thus under estimating the amount of nutrients returnable to the soil. Not with standing this however, their study indicate that this cropping system returns significant amount of nutrients which can benefit the succeeding maize crop. It was necessary therefore, to reassess biomass and nutrient yields, including that for roots of the pigeon pea inorder to quantify the total amount of nutrient yields in this system. In gross terms, the amount of nutrients added to a legume-cereal rotation cropping system depends on the total legume biomass yields (Giller, 2001). The following were the study objectives: (i) assess biomass and nutrient yields for the legumes (ii) Quantify N yields returned to the soil for the monoculture of groundnut and pigeon pea and the intercrop of the groundnut and pigeon pea (iii) Quantify the contribution of pigeon pea root biomass to the soil N pool.

MATERIALS AND METHODS

Study site

The study was conducted on station at Chitedze Agricultural Research Station (13º 59’ 23.2 S”, 033º 38’ 36.8 E”) in Lilongwe, Malawi. The site falls within the Lilongwe plain and receives an average annual rainfall of 875 mm and the rainy season starts in November and ends in April (Phiri *et al.*, 2013). The site has a moderate (pH=5.5) soil reaction, low N (<0.12) and low (≤19 mg P kg^{-1}) to marginally adequate P (≥19 mg P kg^{-1}) (Wendt,1996), with a sandy clay loam to sandy clay texture (Phiri *et al.*, 2013).

Field Experiment

An experiment laid in RCBD and replicated 3 times along side the main experiment was conducted in the 2012/2013 cropping with the following treatments; 1) Long duration pigeon pea; 2) Medium duration pigeon pea; 3) Sole groundnut; 4) Sole groundnut + 25 kg P ha^{-1}; 5) Medium duration pigeon pea + 25 kg P ha^{-1}; 6) Long duration pigeon pea + 25 kg P ha^{-1}; 7) Long duration pigeon pea + groundnut; 8) Long duration pigeon pea + groundnut + 25 kg P ha^{-1}; 9) Medium duration pigeon pea + groundnut; and 10) Medium duration pigeon pea + groundnut + 25 kg P ha^{-1}. P was applied in form of TSP in treatments 4, 5, 6 and 8 to enhance N fixation and hence yield by the legumes, for subsequent comparison with non P treated plots. The field was kept weed free through regular weeding.

Plot description and application of triple super phosphate ($Ca(H_2PO_4)_2.H_2O$) and urea ($CO(NH_2)_2$)

Experimental layout for each treatment plot

The gross plot size was 20 m x 10 m. Open ridges were spaced at 75 cm apart. In the intercrop three pigeon pea seeds were planted per station at 90 cm apart while the groundnut was planted in between the pigeon pea planting stations at 15 cm apart, with one seed per station. In the pure stands three pigeon pea seeds were planted per station at 90 cm apart while the groundnut was planted at 15 cm apart, with one seed per station. Maize was planted on the ridges one seed at 25 cm per planting station. Planting of maize was done in January 2012.

Application of triple super phosphate ($Ca(H_2PO_4)_2. H_2O$)

At planting, all the treatment plots were treated with triple super phosphate (TSP), $Ca(H_2PO_4)_2$. H_2O, at the rate of 25 kg P ha^{-1} to boost N fixation by the legumes due to marginally adequate plant available soil phosphorus. The plot size was 3 m x 4.5 m. In the intercrop three pigeon pea seeds were planted per station at 90 cm apart while the groundnut was planted in between the pigeon pea planting stations at 15 cm apart, with one seed per station. In the pure stands three pigeon pea seeds were planted per station at 90 cm apart while the groundnut was planted at 15 cm apart, with one seed per station. This was done in December, 2012.

TSP was applied to plots according to the treatment structure. At planting time, except for the pigeon pea sole crop treatment plot all the ridges were split open to a depth of 5 cm and 25.2 g of TSP was evenly spread on each ridge. While in the sole pigeon pea treatment 8.4 g of TSP was

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applied per planting station. This was done to achieve the rate of 25 kg P ha^{-1} for the enhancement of nitrogen fixation and the growth and productivity of the legumes.

DATA COLLECTION AND ANALYSIS

Soil sample collection

Soil sampling and preparation for laboratory analysis

Before the experiment in season one, a composite soil sample made from twenty four randomly collected soil samples was gathered from the experimental site as described by Okalebo *et al.*, (2000). The sample was air dried at Chitedze Agricultural Research Laboratory and then passed through a 2 mm sieve in preparation for soil physical and chemical analysis.

Biomass and grain yield assessment for the pigeon pea

Grain yield assessment was done at physiological maturity of the two pigeon pea varieties. Pods were harvested from a 2 m x 2 m net plot. These were shelled and weighed (seeds, grains and husks) in August, 2013. Assessment of the amount of litter for each treatment plot was done by collecting all defoliated leaves from the ground on one planting station (90 cm x 75 cm). Fresh leaves and twigs were also weighed from the 2 m x 2 m net plot. Roots from pigeon pea plants were dug up to a depth of 30 cm by 30 cm diameter and weighed. These were oven dried for 72 hours at 70 ^{o}C to constant weights.

Soil analysis and plant sample analysis

Laboratory soil analysis was done in order to characterize the soil. Soil samples were analyzed for OC, total N, available P, exchangeable K, Mg, Ca and soil pH (H_2O). Soil pH was measured in water (1:2.5) using pH meter (Okalebo *et al.*, 2000). Soil analysis for P, exchangeable K, Mg and Ca was done by Mehlich 3 extraction procedures (Mehlich, 1984) while OC was determined using the colorimetric method (Schumacher, 2002) and total N was determined by Kjeldahl method (Amin and Flowers, 2004). Molybdenum (Mo) was analyzed using the hand held XRF machine (Baranowski *et al.*, 2002). Bulk density was determined using the core sample method (Rowell, 1994). Biomass yields for the legumes were assessed as described by Phiri *et al.*, (2013).

Plant sample analysis

Pigeon pea and groundnut materials were wet digested using nitric and perchloric acids (Oyewole *et al.*, 2012). P in the digests were determined colomerically using the vanado-molybdate method, K was quantified using flame photometer while Ca was determined using

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AAS (Oyewole *et al.*, 2012). Total N was determined by the Kjeldahl method (Amin and Flowers, 2004).

Nutrient yields

Nutrient yields were calculated by multiplying the nitrogen, phosphorus, potassium, and calcium content of pigeon pea and ground tissues with their respective yields.

Statistical analysis

All the data were analyzed using Genstat statistical package and were subjected to analysis of variance at 95% level of confidence. Means were separated by the least significant difference (P<0.05).

RESULTS

Characterization of soil at the study site

The soils' physical and chemical properties at the study site were as presented in Table 1.0.

Table 1.0: The soils' physical and chemical properties at the study site before the experiment

Parameter	Depth					
	0-20 cm	Rating	20-40 cm	Rating	Range	Reference
% Sand	56.9	-	57.5	-	-	-
% Clay	35	-	34.3	-	-	-
% Silt	8.1	-	8.2	-	-	-
Texture class	SC/SCL	-	SC/SCL	-	-	SSSA, (2003)
pH_{H2O}	5.5	Low	5.5	Low	≤ 6.0	Wendt, (1996)
Soil reaction	-	Moderately acid	-	Moderately acid	5.5-5.7	"
% OC	1.4	Medium	1.4	Medium	0.88-1.5%	"
Total N (%)	0.12	Low	0.12	Low	≤ 0.12%	"

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P mg kg^{-1}	22.1	Marginally Adequate	20.5	Marginally Adequate	19-25 mg P kg^{-1}	"
Ex. K cmol kg^{-1}	0.20	Adequate	0.20	Adequate	>0.11-4.0 cmol kg^{-1}	"
Ex. Mg cmol kg^{-1}	0.40	Low	0.30	Low	0.2-0.5 cmol kg^{-1}	"
Ex. Ca cmol kg^{-1}	3.3	Marginally adequate	3.4	Marginally adequate	2.04-3.5 cmol kg^{-1}	"
Total Mo mg kg^{-1}	10.8	High	16.8	High	>5 mg kg^{-1}	Hodges, 2010

N and P content and yield for fresh leaves of pigeon pea

Biomass yields, nutrient concentrations and nutrient yields for fresh leaves of pigeon pea were as presented in Table 2. Significant differences ($p<0.05$) were observed for the yield of fresh pigeon pea biomass across treatments. The concentrations were significantly higher for fresh leaves for pigeon pea both the TSP treated and non TSP treated medium duration pigeon pea-groundnut intercrop (944 kg ha^{-1}), and were significantly lower in fresh leaves for pigeon pea from the TSP treated long duration pigeon pea monoculture (791 kg ha^{-1}). N concentrations were significantly higher in fresh leaves for the crop from the medium duration pigeon pea-groundnut intercrop (3.7%) than for the long duration pigeon pea-groundnut intercrop (3.1%). No significant differences ($p>0.05$) were observed in the concentrations of P in the fresh leaves of the pigeon pea across treatments. This ranged from 0.2 to 0.4%.

On yields no significant differences ($p>0.05$) were observed in the yields of N and P for the fresh leaves. For N this ranged from 25.7 to 32.6 kg N ha^{-1} while for P this ranged from 1.7 to 3.3 kg P ha^{-1}.

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Table 2: N and P in the fresh leaves for pigeon pea and yields at harvest

Treatment	Fresh leaves	N	P	N yield	P yield
	$kg\ ha^{-1}$	%		$kg\ ha^{-1}$	
1. Medium duration pigeon pea + groundnut	944	3.7	0.20	34.7	1.9
2. Long duration pigeon pea + 25 kg P ha^{-1}	791	3.5	0.40	28.0	3.1
4. Medium duration pigeon pea only	909	3.5	0.30	31.9	2.7
5. Long duration pigeon pea + groundnut	830	3.1	0.20	25.7	1.7
6. Medium duration pigeon pea + 25 kg P ha^{-1}	899	3.4	0.35	30.7	3.2
7. Long duration pigeon pea + groundnut + 25 kg P ha^{-1}	914	3.5	0.29	31.8	2.7
8. Medium duration pigeon pea + groundnut + 25 kg P ha^{-1}	944	3.5	0.35	32.6	3.3
10. Long duration pigeon pea only	809	3.4	0.25	27.6	2.0
GM	880	3.5	0.29	30.38	2.58
CV (%)	8.0	9.0	44.0	14.6	44.8
$LSD_{0.05}$	122	0.5	-	-	-

Biomass yields, nutrient concentrations and nutrient yields for pigeon pea litter were as presented in Table 3. Significant differences ($p<0.05$) were observed in the yields of pigeon pea litter across treatments. The yields were significantly higher for pigeon pea litter from the TSP treated medium duration pigeon pea monoculture (824 kg ha^{-1}) than for the long duration pigeon pea-groundnut intercrop (518 kg ha^{-1}). N concentrations were significantly in the litter from the TSP treated long duration pigeon pea-groundnut intercrop (2.6%) than in the litter from long duration pigeon pea-groundnut intercrop (2.1%) and the litter from the TSP treated medium duration pigeon pea monoculture (2.1%). Significant differences ($p<0.05$) were observed in the concentrations of P in the pigeon pea litter across treatments. The concentrations were significantly higher in the litter from; the medium duration pigeon pea-groundnut intercrop, TSP treated long duration pigeon pea monoculture, long duration pigeon pea-groundnut intercrop and the long duration pigeon pea monoculture. In all these treatments P concentrations were at 0.08%. Significantly lower P concentrations were observed in the monoculture for medium duration pigeon pea treated TSP (0.06%).

On yields no significant differences ($p>0.05$) were observed for the yields of N and P for litter. For N this ranged from 11.0 to 17.4 kg ha^{-1} while for P this ranged from 0.4 to 0.5 kg ha^{-1}..

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Table 3: N and P concentrations and nutrient yields for dry leaves for pigeon pea plants at harvest

Treatment	Dry leaves	N	P	N yield	P yield
	kg ha^{-1}		%	kg ha^{-1}	
1. Medium duration pigeon pea + groundnut	661	2.2	0.08	14.4	0.5
2. Long duration pigeon pea + 25 kg P ha^{-1}	597	2.2	0.08	13.3	0.5
4. Medium duration pigeon pea only	686	2.3	0.06	15.8	0.4
5. Long duration pigeon pea + groundnut	518	2.1	0.08	11.0	0.4
6. Medium duration pigeon pea + 25 kg P ha^{-1}	824	2.1	0.06	17.4	0.5
7. Long duration pigeon pea + groundnut + 25 kg P ha^{-1}	652	2.6	0.07	16.9	0.5
8. Medium duration pigeon pea + groundnut + 25 kg P ha^{-1}	671	2.4	0.07	16.1	0.5
10. Long duration pigeon pea only	611	2.3	0.08	14.2	0.5
GM	652	2.3	0.07	14.9	0.5
CV (%)	19	13	16.12	25.6	26.4
$LSD_{0.05}$	230	0.5	0.02	-	-

Biomass yields, nutrient concentrations and nutrient yields for pigeon pea twigs were as presented in Table 4. Significant differences ($p<0.05$) were observed in the yield of twigs for pigeon pea across treatments. The yields were significantly higher for the twigs from the TSP treated medium duration pigeon pea monoculture (882 kg ha^{-1}) and significantly lower for the twigs in the long duration pigeon pea-groundnut intercrop (655 kg ha^{-1}) and the TSP treated long duration pigeon pea monoculture (665 kg ha^{-1}). No significant differences ($p>0.05$) were observed in N concentration for the twigs across the treatments. This ranged from 2.1 to 3.3%.

Significant differences ($p<0.05$) were observed for the concentrations of P for the pigeon pea twigs across treatments. The concentrations were significantly higher for the twigs from the TSP treated long duration pigeon pea monoculture (0.3%), the medium duration pigeon pea monoculture (0.3%) and the TSP treated medium duration pigeon pea monoculture (0.3%). Significantly lower P concentrations were observed for the twigs from the long duration pigeon pea-groundnut intercrop (0.1%) and long duration pigeon pea monoculture (0.1%).

On yields significant differences ($p<0.05$) were observed for the yields of N, P, for the twigs. For N significantly higher yields were observed in the twigs from the medium duration pigeon pea-groundnut intercrop (26.3 kg ha^{-1}) and the TSP treated medium duration pigeon pea monoculture (23.7 kg ha^{-1}). Significantly low N yields were observed for the twigs for the long

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duration pigeon pea monoculture (16.3 kg ha^{-1}). Phosphorus yields were significantly higher for the twigs from the TSP treated medium duration pigeon pea monoculture (2.3 kg ha^{-1}) and were significantly lower in the twigs from; the medium duration pigeon pea-groundnut intercrop (1.0 kg ha^{-1}), long duration pigeon pea-groundnut intercrop (1.0 kg ha^{-1}), the long duration pigeon pea monoculture (1.1 kg ha^{-1}) and the TSP treated long duration pigeon pea-groundnut intercrop (1.2 kg ha^{-1}).

Table 4: N and P concentrations and nutrient yields for twigs of the pigeon pea plants at harvest

	Twigs	N	P	N yield	P yield
Treatment	kg ha^{-1}	%		kg ha^{-1}	
1. Medium duration pigeon pea + groundnut	808	3.3	0.1	26.3	1.0
2. Long duration pigeon pea + 25 kg P ha^{-1}	665	3.1	0.3	20.4	2.0
4. Medium duration pigeon pea only	793	2.6	0.3	20.5	2.2
5. Long duration pigeon pea + groundnut	655	3.3	0.1	21.6	1.0
6. Medium duration pigeon pea + 25 kg P ha^{-1}	882	2.7	0.3	23.7	2.3
7. Long duration pigeon pea + groundnut + 25 kg P ha^{-1}	699	3.2	0.2	22.7	1.2
8. Medium duration pigeon pea + groundnut + 25 kg P ha^{-1}	764	2.7	0.2	20.8	1.6
10. Long duration pigeon pea only	767	2.1	0.1	16.3	1.1
GM	754	2.9	0.2	21.5	1.6
CV (%)	14.0	18	41.2	17.7	39.4
$LSD_{0.05}$	198	-	0.2	6.8	1.1

Biomass yields, nutrient concentrations and nutrient yields for pigeon pea stems were as presented in Table 5. No significant differences ($p>0.05$) were observed for the yields of stems for pigeon pea across treatments. This ranged from 597 to 950 kg ha^{-1}.

Significant differences ($p<0.05$) were observed in N concentrations for the stems across the treatments. Significantly lower stem N concentrations were observed in the long duration pigeon pea-groundnut intercrop (1.6%) and the medium duration pigeon pea monoculture (1.8%) compared to the rest of the treatments except for the TSP treated medium duration pigeon pea monocrop (1.9%) which had an intermediary concentrations of N in the stems. Significant differences ($p<0.05$) were observed in the concentrations of P for the pigeon pea stems across treatments. The concentrations were significantly higher in the stems from the TSP treated long duration pigeon pea monoculture (0.16%) compared with the rest of the treatments except for the TSP treated medium duration pigeon pea monoculture (0.15%) and the non TSP treated medium duration pigeon pea monoculture (0.13%) that had intermediate concentration of N in the stems.

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On yields significant differences ($p<0.05$) were observed in the yield of N, P, for the stems. For N significantly higher yields were observed for stems from the TSP treated medium duration pigeon pea-groundnut intercrop (20.7 kg N ha^{-1}) and the TSP treated long duration pigeon pea monoculture (19.3 kg N ha^{-1}). Significantly low N yields were observed for the stems for the long duration pigeon pea-groundnut intercrop (16.3 kg N ha^{-1}). Phosphorus yields were significantly higher for stems from the TSP treated medium duration pigeon pea monoculture (1.4 kg P ha^{-1}) and were significantly lower for stems from the long duration pigeon-groundnut intercrop (0.6 kg P ha^{-1}) and long duration pigeon pea monoculture (0.7 kg P ha^{-1}).

Table 5: N and P concentrations in stems and yields for pigeon pea plants at harvest

Treatment	Stems	N	P	N yield	P yield
	kg ha^{-1}	%		kg ha^{-1}	
1. Medium duration pigeon pea + groundnut	792	2.0	0.10	15.7	0.8
2. Long duration pigeon pea + 25 kg P ha^{-1}	757	2.5	0.16	19.3	1.2
4. Medium duration pigeon pea only	723	1.8	0.13	13.1	1.0
5. Long duration pigeon pea + groundnut	589	1.6	0.10	9.3	0.6
6. Medium duration pigeon pea + 25 kg P ha^{-1}	915	1.9	0.15	17.5	1.4
7. Long duration pigeon pea + groundnut + 25 kg P ha^{-1}	718	2.4	0.12	17.1	0.9
8. Medium duration pigeon pea + groundnut + 25 kg P ha^{-1}	950	2.2	0.12	20.7	1.1
10. Long duration pigeon pea only	597	2.3	0.12	13.4	0.7
GM	755	2.1	0.13	15.8	0.96
CV (%)	26	13.9	10.7	33.02	30.9
$LSD_{0.05}$	-	0.6	0.03	9.1	0.5

Biomass yields, nutrient concentrations and nutrient yields for pigeon pea roots were as presented in Table 6. No significant differences ($p>0.05$) were observed in the yields of roots for pigeon pea across treatments. This ranged from 507 to 605 kg ha^{-1}. Significant differences ($p<0.05$) were observed in N concentrations for the roots across treatments. Significantly higher N concentrations were observed for the long duration pigeon pea monoculture (1.6%). The concentrations were significantly lower for roots from medium duration pigeon pea monoculture (1.0%) and for the roots from the TSP treated medium duration pigeon pea monocrop (1.0%). Significant differences ($p<0.05$) were observed for the concentration of P for the pigeon pea roots across treatments. The concentrations were significantly higher for roots from the long duration pigeon pea-groundnut intercrop (0.09%) but were significantly lower for roots from the TSP treated medium duration pigeon pea monoculture (0.06%), the TSP treated medium duration pigeon pea-groundnut intercrop (0.06%) and the non TSP treated medium duration pigeon pea-groundnut intercrop (0.06%).

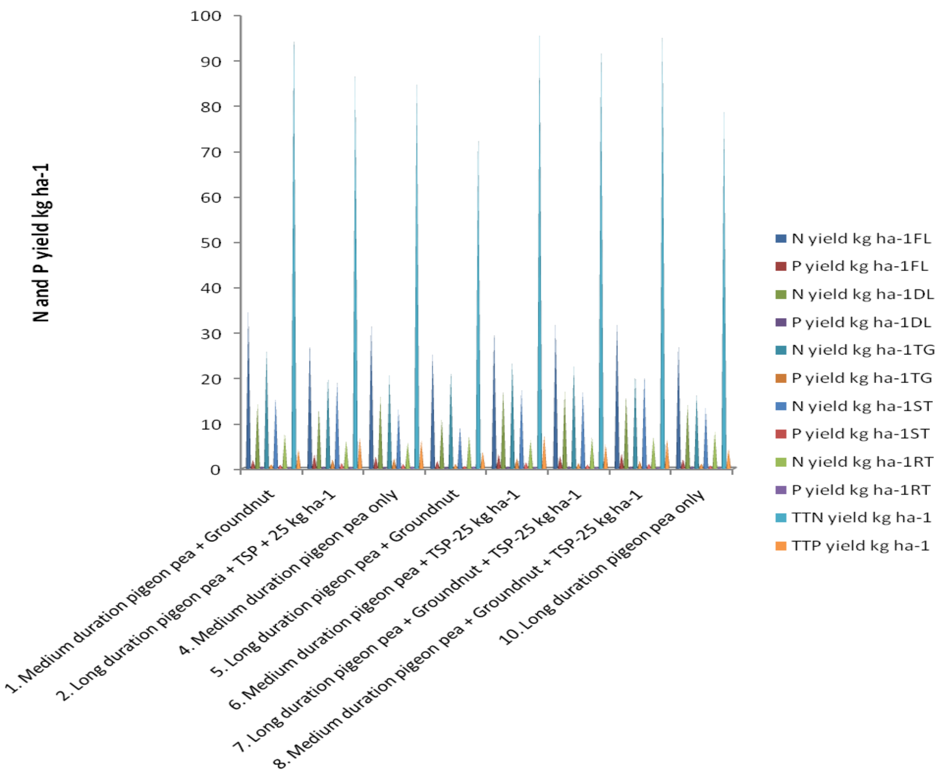
On yields no significant differences ($p>0.05$) were observed for the yields of N and P, for the roots. For N this ranged from 5.7 kg ha^{-1} to 8.2 kg ha^{-1}. For P this ranged from 0.3 kg ha^{-1} to 0.5 kg ha^{-1}

Table 6: N and P concentrations and yields for roots of the pigeon pea plants at harvest

Treatment	Roots	N	P	N yield	P yield
	kg ha^{-1}	%		kg ha^{-1}	
1. Medium duration pigeon pea + groundnut	571	1.3	0.06	7.7	0.3
2. Long duration pigeon pea + 25 kg P ha^{-1}	507	1.2	0.07	6.2	0.4
4. Medium duration pigeon pea only	596	1.0	0.08	5.7	0.5
5. Long duration pigeon pea + groundnut	531	1.4	0.09	7.3	0.5
6. Medium duration pigeon pea + 25 kg P ha^{-1}	605	1.0	0.06	6.3	0.4
7. Long duration pigeon pea + groundnut + 25 kg P ha^{-1}	601	1.1	0.07	6.9	0.4
8. Medium duration pigeon pea + groundnut + 25 kg P ha^{-1}	512	1.4	0.06	7.1	0.3
10. Long duration pigeon pea only	524	1.6	0.08	8.2	0.4
GM	555.9	1.3	0.07	6.9	0.4
CV (%)	12	15.8	15.6	22.2	15.5
$LSD_{0.05}$	-	0.4	0.02	-	-

Summary of nitrogen and phosphorus yields for the pigeon pea

Figure 1 summarizes the yields of N and P for the pigeon pea. N yields for the fresh leaves of the crop ranged from 27.6 to 34.7 kg ha^{-1} while the yields of P ranged from 1.7 to 3.3 kg ha^{-1}. N yields for dry leaves ranged from 11.0 to 17.4 kg ha^{-1} while the yields of P ranged from 0.4 to 0.5 kg ha^{-1}. N yields in twigs ranged from 16.3 to 26.3 kg ha^{-1} while the yields of P ranged from 1.0 to 2.3 kg ha^{-1}. N yields for stems ranged from 9.3 to 20.7 kg ha^{-1} while the yields of P ranged from 0.7 to 1.4 kg ha^{-1}. N yields for roots ranged from 5.7 to 8.2 kg ha^{-1} while the yields of P ranged from 0.3 to 0.5 kg ha^{-1}. The sum total for N yields for the crop ranged from 74.9 to 98.8 kg ha^{-1} while the yield of P ranged from 3.7 to 6.8 kg ha^{-1}.



FL=fresh leaves; DL=dry leavesor litter; TG=twigs; ST=stems; RT=roots; TT=total

Figure 1: Nitrogen and phosphorus yields for the pigeon

DISCUSSION AND CONCLUSION

For the pigeon pea, the N and P yields (Figure 1) were lower for the dry leaves compared with the fresh leaves because some N and P was remobilized to other plant parts during the senescence of defoliating leaves (Fischer, 2007). The N and P content was lower for the stems than the twigs and leaves (Figure 1) as the stems contain more lignin and fibre (Norton, 1992). N yields for roots falls within the yields range of 5 and 15 kg N ha^{-1} reported for intercropping systems involving legumes (Nnadi and Haque, 1986). Overall, the results have shown that much of the N contribution to the soil N pool comes from the above ground biomass as compared with the below ground biomass. Though modest the contribution of roots to soil N cannot be overlooked since the nutrient even after immobilization, a temporally state, largely is available for uptake by succeeding crops in a rotation system as it does not get complexed in the soil as is the case with phosphorus.

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