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Research note: Establishment, biological nitrogen fixation and nutritive value of *Arachis pintoi* (CIAT 18744) in western Kenya

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Abstract

Field experiments were conducted between 2008 and 2009 cropping seasons to evaluate growth, nitrogen fixation and fodder quality of *Arachis pintoi* (CIAT 18744) at 5 sites in western Kenya. Differences in seedling emergence (33–52%), start of flowering (49–60 days after planting) and cumulative dry matter production were measured. The highest dry matter yield (3.1 t/ha) was produced on a moderately fertile alfisol and the lowest (1.7 t/ha) on a degraded ultisol, with corresponding pod yields of 1.3 t/ha and 0.8 t/ha. Estimates of nitrogen derived from the atmosphere (%Ndfa) by ^{15}N natural abundance were greater than 50% across the 5 sites with the highest percentage on a moderately fertile nitisol. Nitrogen fixation ranged from 23 to 46 kg/ha N and was significantly related (r^2=0.77***) to dry matter production. Crude protein and soluble tannin concentrations and dry matter digestibility of forage were 16–18%, 1.2–1.8% and 60–62%, respectively. These preliminary results are promising but longer-term studies to assess persistence and dry matter yield, especially when *A. pintoi* is planted with a grass and grazed, are warranted. Further studies should address the issue of how the legume might be incorporated in the production systems of farmers.

Introduction

Arachis pintoi (fodder peanut) is a multiple-use, prostrate, stoloniferous, perennial tropical legume (Baruch and Fisher 1996), cultivated as a cover crop in orchards (Firth and Wilson 1995). As a cover crop, *A. pintoi* forms a dense mat of rooted stolons that reduces weed invasion, controls erosion (Dwyer *et al*. 1989) and improves soil fertility through nitrogen fixation (Thomas *et al*. 1997). Unlike many other tropical legumes, *A. pintoi* is persistent and tolerant of acidic conditions, shading, drought and heavy grazing (Baruch and Fisher 1996; Jones and Bunch 2003). Limitations observed with *A. pintoi* include slow initial establishment in the field (Castillo 2003), which could depend on the accession used and inherent soil conditions (Jones 1993). Although much has already been documented on *A. pintoi* in other parts of the world, little is known on the legume in east Africa, since it has not been cultivated in this region. Therefore, our objectives were to evaluate growth, nitrogen fixation and nutritive value of *A. pintoi* in western Kenya.

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Materials and methods

Description of experimental sites

Field experiments were conducted between the short rains season (August-November) 2008 and long rains season (March-June) 2009 on 5 sites: a moderately fertile nitisol, a degraded alfisol, a moderately fertile alfisol, a degraded ultisol and a moderately fertile ultisol, following Diwani (2009). The main difference between sites was in soil characteristics (Table 1) as elevation, temperatures and annual rainfall were similar. On the moderately fertile nitisol, trials were conducted at Kenya Agricultural Research Institute (KARI) Kakamega, while the other sites were located on private farms.

Experimental design

There were 4 plots on each site, measuring 6 m x 5 m. Phosphorus (30 kg/ha P) fertiliser was

Table 1. Environmental characteristics of 5 sites in western Kenya.

Parameter	Site[1]				
	MF nitisol	D alfisol	MF alfisol	D ultisol	MF ultisol
Elevation (masl)	1534	1557	1558	1600	1569
Latitude	N 00° 16.96’	N 00° 18.98’	N 00° 19.18’	N 00° 13.86’	N 00° 14.55’
Longitude	E 034° 46.07’	E 034° 47.86’	E 034° 47.79’	E 034° 51.45’	E 034° 51.13’
Annual rainfall (mm)	1977	1612	1612	2231	2231
Mean temperature (°C)	18-21	18-21	18-21	18-21	18-21
Sand (%)	12.9	55.7	61.2	12.0	10.8
Silt (%)	33.6	19.1	20.0	40.1	27.0
Clay (%)	53.5	25.2	18.8	47.9	62.2
pH (H_20)	5.4	5.6	5.4	5.6	4.9
Organic C (%)	3.6	1.3	0.8	2.2	2.5
Total N (%)	0.3	0.2	0.2	0.2	0.3
Extractable P (mg/kg)	3.1	5.4	8.4	2.0	12.7
Exchangeable K (cmol/kg)	0.8	0.3	0.2	0.6	0.9

[1]MF = moderately fertile; D = degraded.

applied during seedbed preparation. *Arachis pintoi* (CIAT 18744) seeds were inoculated with rhizobium (CIAT 3101) and sowed (1 grain per hole) 5 cm deep at a spacing of 20 cm x 15 cm between August 16 and 23, 2008 at the 5 sites. Maize (HB 520) was planted from September 1 to 6, 2008 for the short rains season and from March 25 to 30, 2009 for the long rains season, at a spacing of 25 cm x 60 cm, to serve as a reference for ^{15}N analysis. Treatment plots were hand-weeded at 2, 4 and 6 weeks after planting. No pesticides or fungicides were used.

Measurements and sample preparation

Emergence, flowering, biomass production, pod yield and tolerance to diseases (pests were not evaluated) were assessed. Emergence was evaluated at 4 weeks after planting by counting the number of emerged plants and expressing this as a ratio of sown grains. Start of flowering was defined as the time when 50% of *A. pintoi* plants had flower buds. At 12 months after planting (MAP), all plants in a 60 cm x 60 cm quadrat in 2 replicates at each site were harvested, pooled and weighed to obtain fresh weight, and a representative sub-sample of 200 g was oven-dried at 70°C for 48 h to constant weight to determine total dry matter production. Maize plants close to *A. pintoi* were cut above ground level, chopped, mixed and oven-dried at 70°C for 48 h to constant weight. Below-ground biomass production of *A. pintoi* was not evaluated in this study. Dried sub-samples of *A. pintoi* and neighboring maize plants were finely ground and stored for chemical analysis. Pod yield was evaluated at 12 MAP by digging to a depth of 20 cm within the 60 cm x 60 cm quadrats used to estimate total biomass production. All *A. pintoi* pods in the soil were recovered by sieving and hand-sorting. The pods were washed and sun-dried for 7 days before weighing. Disease infestation was visually rated between 10 and 12 MAP on a scale of 1–5 (Ojiem 2006), where 1 represented very severe disease symptoms and 5 no observable disease symptoms.

Nitrogen fixation

Five mg samples from the *A. pintoi* and maize samples were analysed for N and delta-15-nitrogen ($\delta^{15}N$) contents with an ANCA mass spectrometer (SL 20-20, PDZ Europa). The B-value (natural discrimination of heavy ^{15}N isotope by nitrogenase enzyme complex) of *A. pintoi* was not available. Hence, the B-value for *A. hypogaea* (-1.887‰) obtained from Maskey *et al*. (2001) was used. Nitrogen derived from the atmosphere (%Ndfa) was estimated by ^{15}N natural abundance (^{15}NNAM) according to equation (1) and nitrogen fixation was calculated as in equation (2) (Gathumbi *et al*. 2002):

B represents the $\delta^{15}N$ of *A. pintoi* (*A. hypogaea* in this case) grown in N-free medium and TDM is total dry biomass of *A. pintoi.*

Amount of nitrogen derived from the soil (%Ndfs) was obtained by subtracting %Ndfa from 100. Total nitrogen accumulated by *A.*

$$\text{Nitrogen from } N_2 \text{ fixation (\%Ndfa)} = \left(\frac{\delta^{15}N_{maize} - \delta^{15}N_{A\ pintoi}}{\delta^{15}N_{maize} - B} \right) x\,100 \quad (1)$$

$$N_2 \text{ fixed} = \left(\frac{\%Ndfa}{100} \right) \text{x quantity of N in TDM} \quad (2)$$

pintoi was calculated by adding N from nitrogen fixation to N from soil.

Chemical analyses

Sub-samples of ground *A. pintoi* were analysed for N, P, K, soluble tannins and dry matter digestibility. P was measured colorimetrically with a spectrophotometer (Eppendorf Ecom 6122), while K was measured with a flame photometer (Eppendorf Elex 6361) after dry-ashing (5 hours at 550°C followed by 4 hours at 450°C after ash dissolution in saturated NH_4NO_3 solution) and extraction with 6M HCl (Ngome 2006). Soluble tannins and dry matter digestibility were measured by the methods of AOAC (1980).

Results

Emergence, total dry matter production and pod yield differed across the 5 sites (Table 2). Emergence ranged between 33 and 52%, with the best results obtained on the moderately fertile alfisol. Flowering started between 49 and 60 days after planting and continued throughout the wetter parts of the cropping seasons. Total dry matter during the first year was highest (3.1 t/ha) on the moderately fertile alfisol and lowest (1.7 t/ha) on the degraded ultisol as were pod yields (1.3 and 0.8 t/ha, respectively). Mild disease symptoms, particularly leaf spots and foliar blight, were observed at 10 MAP across the sites.

The amount of $\delta\ ^{15}N$ in maize and *A. pintoi* averaged 5.9‰ and 2.6‰, respectively, across the 5 sites. The percentage of nitrogen in *A. pintoi* derived from the atmosphere was highest (63%) on the moderately fertile nitisol followed by degraded alfisol (57.4%), moderately fertile alfisol (55.4%), moderately fertile ultisol (53%) and degraded ultisol (51%). Nitrogen fixation varied across the 5 sites as did total nitrogen accumulation (Table 3). There was a positive and highly significant relationship (r^2=0.77***) between total dry matter production and nitrogen fixation (Figure 1).

N, P and K concentrations in dry matter of *A. pintoi* were influenced by site (Table 4). The highest N and K concentrations were in the MF nitisol.

Discussion

This study has provided preliminary data suggesting that the accession of *A. pintoi* used could produce reasonable yields of forage (1.7–3.1 t/ha

Table 2. Growth and yield of *Arachis pintoi* (CIAT 18744) at 5 sites in western Kenya. Values are means of 4 replicates.

Site[1]	Emergence (%)	Flowering (DAP)[2]	TDM (t/ha)	Pod yield (t/ha)
MF nitisol	50.4±4.3[3]	49	2.6±0.1	1.0±0.1
D alfisol	35.4±3.4	56	2.4±0.3	1.0±0.1
MF alfisol	52.2±4.5	54	3.1±0.2	1.3±0.2
D ultisol	36.4±2.4	60	1.7±0.3	0.8±0.1
MF ultisol	33.4±4.4	60	2.1±0.2	0.9±0.1

[1]MF = moderately fertile; D = degraded.

[2]DAP = days after planting.

[3]± = standard deviation.

Table 3. Nitrogen fixation (BNF-N) and total nitrogen accumulation (TN) of *Arachis pintoi* (CIAT 18744) at 5 sites in western Kenya. Values are means of 4 replicates.

Site	BNF-N (kg/ha N)	TN (kg/ha N)
Moderately fertile nitisol	46.5±5.4[1]	73.9±7.6
Degraded alfisol	33.5±6.5	59.1±6.1
Moderately fertile alfisol	45.6±4.5	82.1±6.5
Degraded ultisol	23.3±8.7	45.2±8.1
Moderately fertile ultisol	29.8±2.0	56.4±3.2

[1]± = standard deviation.

DM) in the first year, when sown as pure stands into weed-free situations in western Kenya. Elsewhere, *A. pintoi* is observed to persist in well grazed legume-grass pastures (Jones 2001), and further studies are warranted to determine how this species would perform when planted with grasses, especially in terms of establishment, persistence and dry matter yield.

While emergence varied from 33–50%, the germination rates for viable seed could have been higher as we did not do viability assessments on the seed before sowing. Flowering, dry matter production and pod yields of *A. pintoi* in this study were consistent with previous studies (Argel and Pizzaro 1992; Firth and Wilson 1995; Ibrahim and Mannetje 1998). The lower dry matter and pod yields on the heavier-textured ultisols support earlier reports from Colombia (Baruch and Fisher 1996) and Mexico (Castillo 2003), that *A. pintoi* performs better on lighter soils.

The total N accumulated by *A. pintoi* in this study showed that a considerable amount of nitrogen may be obtained from nitrogen fixation by the legume, which could be valuable in smallholder farming systems in east Africa. Though estimates of nitrogen fixation by *A. pintoi* in this

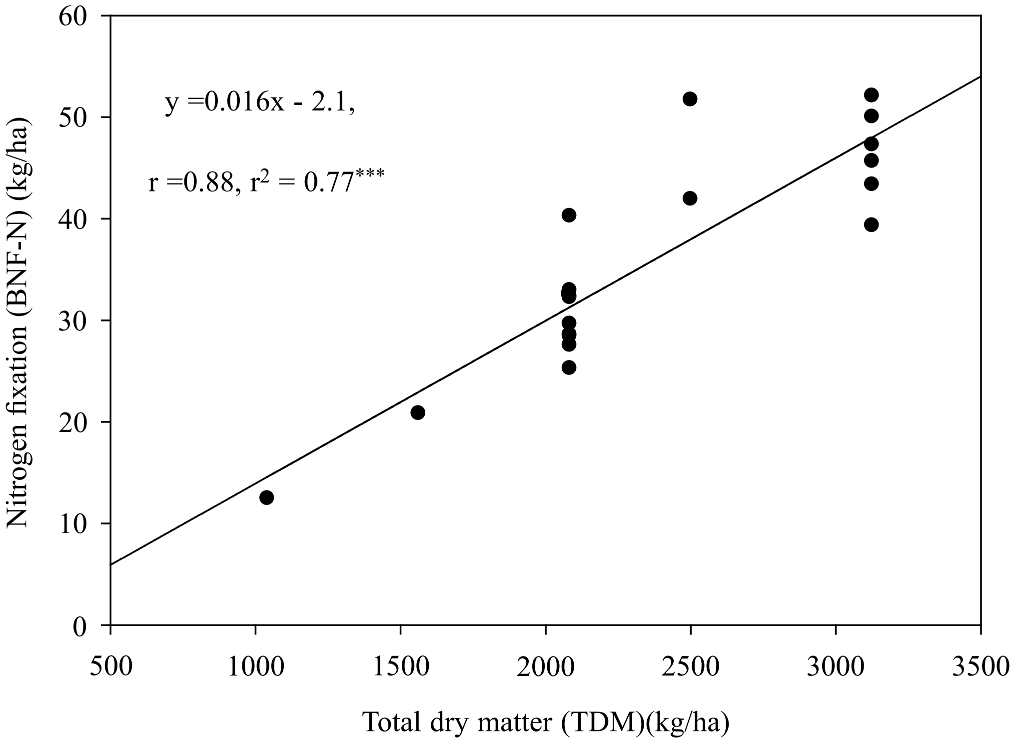

Figure 1. Relationship between nitrogen fixation and total dry matter production of *Arachis pintoi* (CIAT 18744) in western Kenya. Number of data points (n) = 20.

Table 4. Nutritive value of *Arachis pintoi* (CIAT 18744) at 5 sites in western Kenya. Values are means of 4 replicates.

Site[1]	Nitrogen (%)	Phosphorus (%)	Potassium (%)	Soluble tannins (%)	Dry matter digestibility (%)
MF nitisol	2.9±0.14[2]	0.32±0.01	0.38±0.06	1.4±0.07	62.0±0.2
D alfisol	2.5±0.19	0.34±0.02	0.18±0.08	1.4±0.03	60.5±0.3
MF alfisol	2.6±0.21	0.35±0.02	0.21±0.15	1.2±0.02	61.4±0.2
D ultisol	2.7±0.14	0.29±0.01	0.32±0.07	1.8±0.09	61.4±0.1
MF ultisol	2.7±0.16	0.35±0.01	0.48±0.03	1.6±0.11	61.5±0.1

[1]MF = moderately fertile; D = degraded.

[2]± = standard deviation.

study were similar to that observed in Colombia (Thomas *et al*. 1997), it is necessary to consider differences that may occur in the proportion of nitrogen fixed due to inherent soil nitrogen, cultural practices and invasive weeds.

The high crude protein (16–18%) and low soluble tannin (1.2–1.8%) concentrations and high dry matter digestibility (over 60%) in the forage produced were comparable with earlier studies (Castillo 2003; Sinclair *et al*. 2007). As such, the forage produced by this species would be suitable for use as a supplement to low quality forage in Kenya.

Conclusion

These preliminary data suggest that the accession of *A. pintoi* (CIAT 18744) used is promising in terms of growth, nitrogen fixation and nutritive value in western Kenya. However, the accession was planted in pure stands and was not grazed. Longer-term studies, especially in combination with grasses, *e.g*. kikuyu, under grazing are needed to validate these preliminary findings. Future studies should investigate ways of introducing the legume so that it fits well into the socio-economic environment of the farmers, as suggested by Mapiye *et al*. (2006) to increase adoption of legume-based technologies in smallholder and communal farming systems.

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