Journal of Agriculture and Environmental Sciences
September 2014, Vol. 3, No. 3, pp. 73-89
ISSN: 2334-2404 (Print), 2334-2412 (Online)

Published by American Research Institute for Policy Development
DOI: 10.15640/jaes.v3n3a7
URL: http://dx.doi.org/10.15640/jaes.v3n3a7

Potentials of Indigenous Herbaceous Species for the Improvement of Local Farming Systems in Sudano-Sahelian Zone of Cameroon

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Abstract

Constraints to productivity in the Sudano-sahelian zone of Cameroon are often linked with inadequate herbaceous cover. A study was carried out to evaluate the performance of ten indigenous herbaceous legumes with potentials for use in crop/livestock systems. Data collected on above and belowground performance at 30, 60, 90 and 120 days after planting (DAP) showed significant differences ($p<0.0001$) in all parameters. At 90DAP, plant height ranged from 21.25 cm in *Zornia glochidiata* to 86.9 cm in *Cajanus cajan,* highest biomass was 104.2g for *Crotalaria spectabilis* and 86.4g for *Indigofera hirsuta*, while spread/cover was best for *Vigna radiata* (145.7cm). Root length and density were highest in *Crotalaria spectabilis* (48.83cm and 18.77g). Nodule number was highest in *Desmodium adreudens (*83.36), followed by *Zornia glochidiata (*60.63) and *Indigofera hirsuta* (59.3). Nodule efficiency was generally high for all species, attaining up to 100% in Desmodium (big leaves), implying effective symbiosis between the local rhizobium and the different species. *Crotalaria spectabilis, Indigofera hirsuta* and *Vigna radiata* ranked highest in overall performance. The results have shown that some indigenous herbaceous species possess potentials that could be beneficial in enhancing biodiversity and environmental management goals in a sustainable farming system.

Keywords: Indigenous legumes; herbaceous cover, biomass yield, nodule production, Sudano-sahelian environments

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Introduction

Low herbaceous cover is a major cause of soil fertility loss and poor livestock performance in the Sudano-sahelian region of Cameroon where traditionally, crop production and livestock keeping constitutes over 80% of the livelihoods of the population (Donfack *et al*, 1997). Natural rejuvenation in terms of soil fertility and herbaceous biodiversity, which was formerly assured by prolonged fallows, is no longer feasible due to increased human and livestock pressure on natural resources (Harmand *et al*, 2003). Despite the use of manure and chemical fertilizers, crop yields have been on a steady decline over the years in this region as a result of infertile soils. Yield reduction of 30% has been recorded for some major crops such as cotton and maize over the last 20 years, representing 11kg/ha/yr (Olina, *et al*. 2008). The status of soil fertility which is closely linked to soil organic matter depends on biomass management and loss (Harmand, *et al*. 2003; Anthofer and Kroschel 2005). Erosion, a major cause of loss of soil fertility in this region is closely linked to low soil organic matter resulting from poor soil cover (Roose and Barthès 2004). Soil improving legumes have been used in most cropping systems to provide above and below – ground biomass to increase biological activity and fertility of soils (Njiti and Galiana 1996; Mpairwe, *et al.* 2002; Anikwe and Atuma 2003; Anthofer and Kroschel 2005; Fofana, *et al*. 2005; Mapfumo, *et al*. 2005; Crammer, *et al.* 2006).

In the Sudano-sahelian region of North Cameroon, the introduction of grass and legume species as forage biomass or for soil cover has witnessed a low rate of adoption at farmer level (Onana and Yonkeu 1994; Klein 1995; Onana and Asongwed – Awa 1996; Carsky and Ndikawa 1998; Guibert 2001; Asongwed-Awa and Njoya 2002; Onana, *et al*. 2007). This has been blamed on the in-adaptation and low persistence of the mostly exotic varieties which were used (Dugue 1995; Guibert 2001). Commonly used indigenous legume species in this cereal-based cropping system are grain legumes for human consumption such as groundnuts, cowpeas, pigeon peas and a few leafy vegetables, most of which are cherished and harvested also as crop residues for livestock after grain harvest. Indigenous legume fallows have been proposed as an initial step in meeting the challenge of integrating under-utilized leguminous species into existing farming systems for their above and belowground contributions in environmental sustainability (Mapfumo *et al*. 2005). Their integration in farming systems is aimed at soil fertility improvement, increased herbaceous biomass for livestock and the maintenance of a rich floral biodiversity and soil cover.

This is important in this farming system where current high dependence on mineral fertilizers and feed supplements for crop and livestock production respectively calls for new strategies of enhancing sustainability (Awa, *et al*. 2004; Olina, *et al.* 2008).

This trial was aimed at evaluating the above and belowground productivity potentials of selected indigenous herbaceous legumes of the Sudano-sahelian zone of North Cameroon, that hitherto were considered as weeds, for their beneficial attributes which can be used in the sustainable management of local farming systems. Specifically, we shall measure and compare above and belowground parameters of the selected indigenous species and their potential contribution in the improvement of farming systems.

Materials and Methods

The Study Area

The trial was conducted at the Institute of Agricultural Research Station (IRAD), Garoua which is situated in the North region of Cameroon around latitude 9°N and at an average elevation of 400m above sea level. The climate is Sudano-sahelian, with average annual precipitation of 900 mm. Rainfall is monomodal, from May to September (4 - 5 months). Mean temperatures are around 30° Celsius and may go up to 40° and above during the hottest months of the year (March – May). Relative humidity averages 40% and 80% in the dry and rainy seasons respectively. The soil is ferric luvisols in association with acrisols and regosols, sandy textured and poor in organic matter (IFDC, 1986, Olina *et al,* 2008).

A) Identification and Selection of Indigenous Species for Evaluation

A survey was carried out towards the end of the rainy season in 2009 to identify and select indigenous herbaceous species with potentials for use in soil fertility and pasture improvement. Plants selected were those with a good biomass yield and/or soil covering potential. Once selected, 5-10 plants of each plant species were collected and different measurements taken (height, spread, biomass yield and nodule presence). Selected species were rated as good (+), very good (++) or excellect (+++) based on the quality of the observed or measured parameter (Table 1).

Their taxonomic classification was done using the identification guides of Le Bourgeois and Merlier (1995) and Akobundu and Agyakwa (1987).

B) Evaluation of the Productivity Potentials of Selected Indigenous Herbaceous Species

Ten indigenous herbaceous legumes were selected and established in pots (on – station) to evaluate their performance. Surface soil (0-15cm depth) was collected from an area that had been fallowed for at least three years. Soil samples were rid of coarse particles (stones) and put in pots containing 8kg of soil. Four pots per species constituted one experimental unit since harvesting for data collection was done by destructive sampling at different dates after planting (30, 60, 90 days and end of vegetative period). A total of 160 pots were used (16 pots per species). The experimental unit was arranged in a completely randomized design with four replications, each containing 10 experimental units. Each of the 10 plant species constituted a treatment. Inorganic fertilizer (simple super-phosphate) mixed with the soil, was applied at the rate of 50 kg/ha during establishment. 10-12 seeds were planted into each pot and later thinned to 6 seedlings after emergence. Weeds were removed weekly by handpicking.

Measurements

Data were collected at 30, 60 and 90 days after planting (DAP) as well as at the end of the vegetative cycle for each species. All measurements were made on 4 plants per pot, and 4 pots per treatment. Measurements were on the following:

- **Growth characteristics (germination rate, flowering, seeding and maturity)**: After planting, germination rate was observed and noted up to 10days after planting. The dates of onset of flowering, 50% flowering, seeding and maturity were recorded.
- **Plant aboveground performance (height, biomass, branching, spread,):** At the different sampling dates (30, 60, 90 days and end of cycle), plant height, branching and spread were measured using a measuring tape or ruler. The plant was cut at ground level and weighed to obtain the above-ground biomass. At 90 DAP, samples were collected and dried in the oven at 60°C to constant weight and used for dry matter calculations.

- **Plant belowground performance (Root: length and density, Nodule: number and efficiency):** After cutting off the plant top, the pots containing the roots were saturated with water in a basin and the soil carefully washed off until the roots were recovered. Root length was measured at the longest point using a ruler or tape and root biomass weighed. The nodules were carefully plucked off the roots and counted, then split into two to examine for presence or absence of coloration.

Statistical Analysis

Quantitative continuous data from experimentation was analysed using ANOVA or ANCOVA where co-variants were present. Chi square test was performed on qualitative data. The statistical package used was XLSTAT.

Results and Discussion

1. Characteristics of Selected Indigenous Herbaceous Species

The initial species selection was based on biomass yield, soil covering capacity and presence of nodules. Identified and selected species are presented in Table 1. All ten species showed some potential for biomass and soil cover. *Cassia obtusifolia* and *Cassia occidentalis*, showed no signs of nodulation. These two were however included because of their abundance and local use in the region. They are eaten as vegetable (*Cassia obtusifolia*), used for tea (*Cassia occidentalis)* and for medicinal purposes. They can equally provide good cover and mulch if maintained for such purposes.

Table 1: Species Selected for on-Station Testing Based on Observed Field Performance

Species	Plant type	Biomass potential	Cover potential	Nodulation potential
Cajanus cajan	**Shrubby**	**+++**	**++**	**+**
Cassia obtusifolia	**Erect**	**+**	**+**	**absent**
Cassia occidentalis	**Erect**	**++**	**+**	**absent**
Desmodium adreudens	**Prostrate**	**++**	**+**	**+++**
Desmodium (big leaf)	**Erect**	**++**	**++**	**+**
Crotalaria spectabilis	**Erect**	**+++**	**++**	**++**
Indigofera hirsuta	**Erect**	**+++**	**++**	**++**
Indigofera nummulariifolia	**Prostrate**	**++**	**+++**	**++**
Vigna radiata	**Creeping/climbing**	**+++**	**+++**	**+**
Zornia glochidiata	**Tufted**	**+**	**+**	**++**

+ = gradient of observed factors (+ = good, ++ = very good, +++ = excellent)

2: Pot Evaluation of Selected Indigenous Species

2.1: Growth Characteristics (Germination, Flowering, Seeding and Maturity)

Onset of germination ranged from 3 – 5 days. *Crotalaria spectabilis* was the first to germinate at 3 days after planting (DAP). Early flowering was noted for *Vigna radiata* at 55 DAP, followed by *Indigofera nummulariifolia* at 68 DAP. Another set of species flowered from 80 – 87 DAP while the last set flowered at 95 – 120 DAP (Table 2). Fruit formation was earliest for *V. radiata* at 70 DAP followed by *I. nummulariifolia* at 85DAP. Seeds of four species: *Vigna radiata, Indigofera nummulariifolia, I. hirsuta and Zornia glochidiatia* matured before 120 DAP, while the rest of the species matured after 120 DAP. This first group can be considered medium cycled and the second group long-cycled. Establishment was generally good for all implanted species.

Table 2: Phenology / Growth Characteristics of Selected Indigenous Species

Species	Germination (DAP)	Flowering (DAP)	Fruit formation (DAP)	Maturation (DAP)	Flower colour
Cajanus cajan	5	120	132	150	yellow
Cassia obtusifolia	4	80	95	122	yellow
Cassia occidentalis	5	95	112	125	yellow
Desmodium adreudens	5	110	125	132	red
Desmodium (big leaf)	4	85	97	122	red
Crotalaria spectabilis	3	107	115	125	yellow
Indigofera hirsuta	5	87	103	118	pink
Indigofera nummulariifolia	5	68	85	107	pink
Vigna radiata	5	55	70	95	white
Zornia glochidiata	4	85	100	115	yellow

DAP= Days after planting

2.2: Aboveground Performance of Selected Indigenous Herbaceous Species

2.2.1: Plant height

Plant height was significantly different for the different species at different planting dates. As early as 30 DAP, there was significant difference between plant height in the different species ($p<0.0001$) (Table 3). At 60 and 90 DAP, *Cajanus cajan* was closely followed by *Crotalaria spectabilis*, *Indigofera hirsuta* and *Cassia obtusifolia*.

Most species attained maximum heights at 90 DAP except *C. cajan* which still obtained a significant increase at 120 DAP and can actually grow upto 4 m in height (Arbonnier, 2002), probably attesting to its semi perenial nature.

Table 3: Plant Height of Selected Herbaceous Species at Different Dates After Planting (DAP)

Species	Height			
	30DAP	60DAP	90DAP	120DAP
Cajanus cajan	24.7[a]	47.9[a]	86.9[a]	109.8
Cassia obtusifolia	21.71[b]	45.38[a]	62.07[b]	67.07
Cassia occidentalis	16.22[d]	25.33[c]	54.92[b]	34.00
Crotalaria spectabilis	12.32[e]	36.725[b]	79[a]	69
Desmodium (large)	18.93[c]	48.25[a]	44.63[c]	47.30
Desmodium adreudens	6.9[g]	15.5[ef]	29.1[d]	3.5
Indigofera hirsuta	10.79[f]	29.49[bc]	77.85[a]	75.08
Indigofera nummulariifolia	12.78[e]	19.92[de]	30.46[d]	12.00
Vigna radiata	9.22[f]	23.11[cd]	13.23[e]	13.89
Zornia glochidiata	9.29[f]	13.13[f]	21.25[de]	2.03

[abcdefg]Column means with different superscripts are significantly different ($p<0.0001$)

2.2.2: Aboveground biomass production

Aboveground biomass yields were significantly different ($p<0.0001$) at all sampling dates (Table 4).

At 30 DAP, biomass yields ranged from 0.44 to 2.8 g/plant in *Desmodium adreudens* and *Cassia obtusifolia* respectively. Biomass yield at 60 DAP was highest in *Vigna radiata* with 29.98 g/plant and closely followed by *Crotalaria spectabilis* and *Indigofera hirsuta* with 20.43 and 20.31 g/plant respectively. High biomass productions at 60 DAP with *Vigna radiata* is a good indication for early soil cover and competition with other weeds. These species can serve in soil improvement programs where early aboveground biomass accumulation is a key for soil protection, as is being done with Mucuna species (pers. Comm.; Crammer *et al*, 2006).

Table 4: Evolution of Aboveground Biomass of Selected Herbaceous Species at Different Dates After Planting (DAP)

Species	Aboveground biomass		
	30DAP	60DAP	90DAP
Cajanus cajan	2.16[bc]	9.27[bc]	36.96[bc]
Cassia obtusifolia	2.8[a]	12.87[bc]	28.21[c]
Cassia occidentalis	2.1[bc]	7.13[c]	33.51[bc]
Crotalaria spectabilis	1.21[c]	20.43[ab]	104.2[a]
Desmodium (large)	1.9[c]	14.37[bc]	37.01[bc]
Desmodium adreudens	0.44[e]	6.19[c]	21.99[c]
Indigofera hirsuta	1.1[d]	20.31[ab]	81.36[ab]
Indigofera nummulariifolia	2.21[bc]	6.11[c]	9.31[c]
Vigna radiata	2.53[ab]	29.98[a]	55.25[abc]
Zornia glochidiata	0.91[e]	4.24[c]	4.72[c]

[abcde]Column means with different superscripts are significantly different ($p<0.0001$)

Biomass production was highly progressive in all species from 30 to 90 DAP except in *Z. glochidiata* where the progress was quite slow, yielding 0.91 to 4.72 g/plant at 30 and 90 DAP respectively. This species is however, noted as highly palatable for livestock and provides excellent forage in pastures of Sudano-sahelian environments (Akpo *et al*, 2002; Mbaye *et al,* 2002).

2.2.3: Aboveground performance at 90 days after planting (DAP)

There were significant differences ($p<0.001$) height, herbage biomass, branching and spread especially at 90 days after planting, which was a point of maturity for most of the species (Table 5).

Table 5: Aboveground Performance of Selected Indigenous Herbaceous Species at 90 Days after Planting (DAP)

Species	Height	Herbage yield (g)	Branching 1°	Branching 2°	Spread (cm)
Cajanus cajan	86.9^{a}	36.96^{bc}	4.09^{abc}	0^{c}	15.4^{cd}
Cassia obtusifolia	62.2^{b}	28.2^{c}	4.57^{ab}	8.86^{bc}	25.27^{bcd}
Cassia occidentalis	50.59^{b}	40.9^{bc}	0.57^{c}	0^{c}	6.65^{d}
Crotalaria spectabilis	79^{a}	104.2^{a}	4.17^{abc}	3.0^{c}	29.5^{bcd}
Desmodium (large)	44.63^{c}	37.01^{bc}	6.2^{a}	5.13^{c}	25.5^{bcd}
Desmodium adreudens	29.13^{d}	22.39^{c}	4.64^{ab}	29.43^{a}	44.13^{b}
Indigofera hirsuta	77.85^{a}	86.4^{ab}	6.75^{a}	5.25^{c}	38.42^{bc}
Indigofera nummulariifolia	30.46^{d}	9.31^{c}	2.86^{bc}	2.0^{c}	25.07^{bcd}
Vigna radiata	13.23^{e}	55.3^{abc}	4.25^{ab}	4.5^{c}	145.77^{a}
Zornia glochidiata	21.25^{de}	4.72^{c}	6.88^{a}	10.81^{b}	18.41^{cd}

^{abcde}Column means with different superscripts are significantly different ($p<0.0001$)

Plant height range was 21.25 cm in *Zornia glochidiata* to 86.9 cm in *Cajanus cajan* at 90DAP. Best herbage biomass yield was obtained from *Crotalaria spectabilis* and *Indigofera hirsuta* (104.2 and 86.4g respectively). Spread/cover was best for *Vigna radiata* (145.7cm) while primary and secondary branching was highest in *Zornia glochidiata* and *Desmodium adreudens* respectively, thus confirming their tufted and prostrate natures. Generally at 90 DAP, *Crotolaria spectabilis* and *Indigofera hirsuta* were best for height and herbage yield, while *Vigna radiata* had the best cover/spread. *Cajanus cajan* on the other hand, being a semi-perennial could grow upto 4 m and would produce much more in terms of biomass yield if well managed for livestock feeding. Its grain yield is also of added advantage in households for food (Anikwe and Atuma, 2003). The relatively high herbage biomass production and good spread by *Crotalaria spectabilis*, *Indigofera hirsuta* and *Vigna radiata* are indications for good soil cover and mulch accumulation, as well as forage for livestock if palatable. Effective soil cover and mulch will protect the soil from the impact of raindrops and excessive erosion, direct sunrays and excess nutrient volatilization while conserving moisture for crop use.

2.3: Belowground Performance -Roots (Length, Density), Nodules: (Number, Efficiency)

2.3.1: Root Length at Different Planting Dates

Root elongation was progressive for all the species with a peak at 60 DAP, after which not much difference was obtained for the majority of species except *Cassia occidentalis, Crotalaria spectabilis* and *Indigofera hirsuta* (Figure 1). At 30 DAP, there was already significant difference ($p<0.0001$) in root length between species with the longest being *Cassia obtusifolia* with 39.49cm, closely followed by *Cajanus cajan* and *Vigna radiata* with 37.28 and 34.2 cm respectively. Higher root elongation in the three species provides opportunity for deeper exploration of the soil to obtain nutrients and water for the crop.

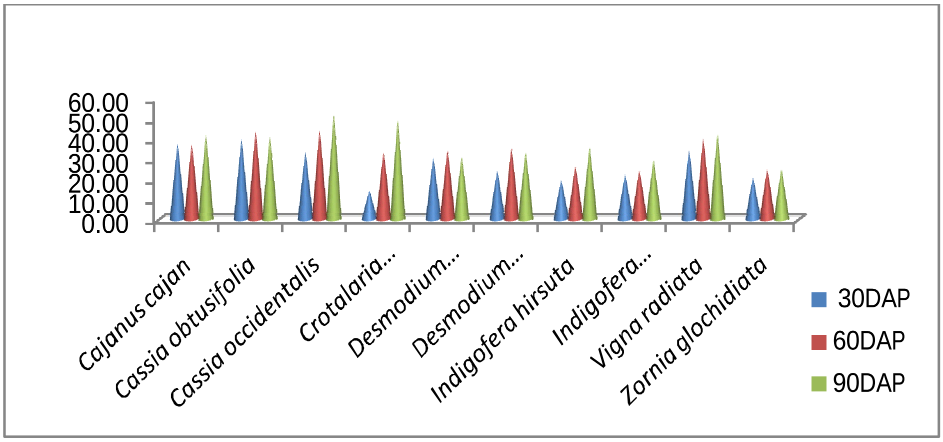

Figure 1: Root Length of Selected Indigenous Herbaceous Legumes

2.3.2.: Root Density at Different Planting Dates

Root density was significantly different ($p<0.0001$) at all stages of development (Table 6). It was highest for *Cassia occidentalis* at 30 DAP, and for *Crotalaria spectabilis* and *Indigofera hirsuta* at 60 and 90 DAP respectively. *Zornia glochidiata*, *Indigofera nummulariifolia* and *Desmodium adreudens* had the lowest root density at all stages. Species with high root density such as *C. spectabilis* and *I. hirsuta* would be very efficient in reducing soil compaction and thus enhance nutrient uptake, since they are more likely to explore the rhizosphere for nutrients, water and mycorrhizal associations.

Table 6: Evolution of Root Density of Selected Herbaceous Species at Different Dates After Planting (DAP)

Species	Root Density		
	30DAP	**60DAP**	**90DAP**
Cajanus cajan	**1.26**[a]	**2.55**[bcde]	**7.8**[bc]
Cassia obtusifolia	**0.86**[bc]	**3.04**[bcd]	**5.18**[cde]
Cassia occidentalis	**1.19**[ab]	**3.67**[bc]	**7.51**[bcd]
Crotalaria spectabilis	**0.39**[de]	**10.31**[a]	**18.77**[a]
Desmodium (large)	**0.28**[e]	**1.87**[cde]	**3.63**[cde]
Desmodium adreudens	**0.07**[e]	**1.68**[cde]	**1.79**[c]
Indigofera hirsuta	**0.17**[e]	**4.53**[b]	**12.85**[ab]
Indigofera nummulariifolia	**0.06**[e]	**0.62**[de]	**0.61**[c]
Vigna radiata	**0.74**[cd]	**3.17**[bcd]	**3.69**[cde]
Zornia glochidiata	**0.03**[e]	**0.71**[e]	**0.29**[c]

[abcde]Column means with different superscripts are significantly different ($p<0.0001$)

2.3.3: Nodule Production and Efficiency at Different Planting Dates

There was a regular increase in nodule production in all the nodulating species, being highest in *Desmodium adreudens* as from 60 – 90 DAP (Figure 2), though early production at 30 DAP was highest in *Vigna radiata* followed by *Indigofera nummulariifolia* (Table 7), confirming reports by Wasermann *et al*, (2000) that nodules are recognisable within 2 – 4 weeks in nodule producing species. Nodule production and efficiency was significantly different ($p<0.0001$) between species at all periods during the growing cycle (Table 7). Percentage efficiency which was estimated by the ratio of coloured nodules observed at the different stages of evaluation, increased in the different species as the plant grew older, attaining 100% in Desmodium (big leaves) at 60 DAP. Percentage efficiency was highest for all species at 60 DAP except in *Indigofera hirsuta* and *I. nummulariifolia* where efficiency went up to 97.4 and 97.11% respectively at 90 DAP. There was a regular increase in nodule production and efficiency as noted from 30 to 60 DAP before dropping at 90 DAP. The reductions observed at 90 DAP may be due to nodules senescence, stimulated by defoliation and other stresses (temperature, humidity) as the plant grows old, and new ones are no longer produced (Miles and Manson, 2000).

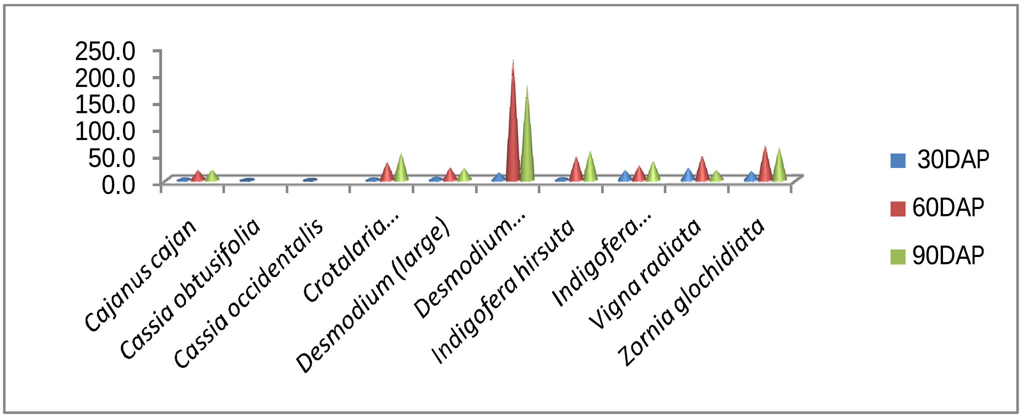

Figure 2: Nodule Production in Selected Indigenous Herbaceous Legumes

The presence of coloration in the nodules, signifying their efficiency suggests effective symbiosis between the rhizobium bacteria in the soil substrate and the roots of the different species. Lack of nodules in the two Cassia species confirms their belonging to the Caesalpiniaceae Sub-Family where only about 23% were noted to produce nodules as against 90 and 97% in Mimosaceae and Papilioneaceae respectively in an evaluation of 3400 legume species (Werner, 1992). This effective symbiosis by most of the species is a sign of adaptation to the indigenous strains of rhizobia in the soil. This local adaptation is a key in our selection of local species for use in the improvement of local farming systems in terms of nitrogen fixing potentials for soil and pasture improvement. *Desmodium adreudens, Vigna radiata, Indigofera hirsuta, I. nummulariifolia, Crotalaria spectabilis, Cajanus cajan* and *Zornia glochidiata* all showed great potentials for nodulation, thus are adapted to local rhizobia.

Table 7: Nodule Efficiency in Terms of Presence (Active) or Absence (Non-Active) of Coloration in Selected Indigenous Herbaceous Species

SPECIES	30DAP			60DAP			90DAP		
	Active	Non-active	% efficiency	Active	Non-active	% efficiency	Active	Non-active	% efficiency
Cajanus cajan	3.25^{de}	2.19^{bcd}	59.74	17.38^{bc}	1^{b}	94.56	15.18^{de}	1.91^{c}	82.82
Cassia obtusifolia	0^{e}	0^{d}	0	0	0	0	0	0	0
Cassia occidentalis	0^{e}	0^{d}	0	0	0	0	0	0	0
Crotalaria spectabilis	5.8^{cd}	0.97^{cd}	85.67	32.75^{bc}	0.63^{b}	98.11	42.67^{ab}	7.50^{c}	85.05
Desmodium (large)	5.69^{cd}	1.25^{cd}	81.99	23.13^{bc}	0^{b}	100	22.40^{cd}	0.13^{c}	99.42
Desmodium adreudens	9.81^{c}	4.44^{b}	68.84	189.69^{a}	16.37^{b}	92.06	49.50^{ab}	13.87^{ab}	78.11
Indigofera hirsuta	4.19^{de}	1.75^{bcd}	70.54	41.38^{bc}	2.69^{b}	93.90	56.17^{a}	1.50^{c}	97.4
Indigofera nummulariifolia	15.06^{b}	3.5^{bc}	81.14	22.94^{bc}	4.31^{b}	84.18	33.57^{bc}	1.0^{b}	97.11
Vigna radiata	20^{a}	2.81^{bcd}	87.68	43.37^{bc}	2.19^{b}	95.19	13.0^{de}	0.92^{c}	93.39
Zornia glochidiata	7.56^{cd}	8.65^{a}	46.64	57.4^{b}	7.4^{a}	88.58	10.62^{de}	6.57^{a}	61.78

^{abcde}Column means with different superscripts are significantly different (p<0.0001)

2.3.4 : Below-Ground Performance at 90 Days After Planting (DAP)

There were significant differences (p<0.0001) between species in all belowground parameters (Table 8). Root length was longest in *Crotalaria spectabilis* and *Cassia occidentalis* (48.83 and 47.7 cm respectively). Root density was highest for *Crotalaria spectabilis* (18.77) and *Indigofera hirsuta* (12.02). Nodule number was very high in *Desmodium adreudens* (183.36) followed by *Zornia glochidiata* and *Indigofera hirsuta with* 60.63 and 59.3 respectively. The two Cassia species did not produce any nodules. At 90 DAP, *Cajanus cajan,* considered amongst the major nitrogen fixing species (Brewbaker, 1990), had 19.09 nodules, and was least amongst all the other species where nodule production ranged from 23.08 in *Vigna radiata* to 183.36 in *Desmodium adreudens*. Being a semi-perennial, nodule production in *Cajanus cajan* might still have been progressing.

High and early nodule production in *Desmodium adreudens, Zornia glochidiata,* and *Indigofera hirsuta* is an indication of potentials for soil fertility improvement on farmland, quality forage in pastures as well as low competition for soil nutrients in associations with graminae.

Table 8: Belowground Performance of Indigenous Species at 90 Days After Planting

Species	Root length (cm)	Root density (no.)	Nodule production (no.)
Cajanus cajan	41.36^{ab}	7.8^{bc}	19.09^{cde}
Cassia obtusifolia	38.107^{abc}	5.56^{cde}	0
Cassia occidentalis	47.72^{a}	5.69^{bcd}	0
Crotalaria spectabilis	48.83^{a}	18.77^{a}	50.17^{bc}
Desmodium (large)	30.57^{cd}	3.63^{cde}	22.53^{cde}
Desmodium adreudens	33.21^{bcd}	1.72^{c}	183.36^{a}
Indigofera hirsuta	35.96^{abc}	12.02^{ab}	59.3^{b}
Indigofera nummulariifolia	29.07^{cd}	0.61^{c}	35.5^{bcd}
Vigna radiata	41.21^{ab}	3.87^{cde}	23.08^{cde}
Zornia glochidiata	24.59^{d}	0.29^{c}	60.63^{b}

^{abcde}Column means with different superscripts are significantly different ($p<0.0001$)

3: Performance Ranking of Species

Ranking the ten species based on their overall performance as per some soil improvement parameters, *Crotalaria spectabilis,* and *Indigofera hirsuta* scored 12 points each followed by *Vigna radiata* with 10 (Table 9). The species with the least score (6) were *Zornia glochidiata*, *Indigofera nummulariifolia* and *Cassia obtusifolia*. However, when viewed individually, these species do have special attributes which could be important at one point in time depending on the farmer's need. *Zornia glochidiata* is a very palatable and high forage quality legume which is common in Sudano-sahelian pastures, even-though with low herbage biomass yields (Akpo et al, 2002). Farmers observed that soil under *Indigofera nummulariifolia* is quite cool and thus could be useful in soil improvement schemes with fallow species in view. On the other hand, the importance of *Cassia obtusifolia* in households as food vegetables and *Cajanus cajan* as grain cannot be neglected. The final decision will be that of the farmer, depending on his/her immediate needs.

Table 9: Ranking of 10 Indigenous Herbaceous Legumes for Observed Potentials for the Improvement of Farming Systems of Sudano-Sahelian Regions

Species	Aboveground biomass	Cover	Root length	Root density	Nodule number	Total Score
Cajanus cajan	++	+	+++	++	+	9
Cassia obtusifolia	+	+	++	++	absent	6
Cassia occidentalis	++	+	+++	++	absent	8
Crotalaria spectabilis	+++	+	+++	+++	++	12
Desmodium (large)	++	+	++	+	+	7
Desmodium adreudens	+	++	++	+	+++	9
Indigofera hirsuta	+++	++	++	+++	++	12
Indigofera nummulariifolia	+	++	+	+	+	6
Vigna radiata	++	+++	+++	+	+	10
Zornia glochidiata	+	+	+	+	++	6

Ranking model: + = good, ++ = very good, +++ = excellent

Conclusion

This agronomic evaluation of indigenous herbaceous legumes has shown different root and aerial biomass characteristics which could be managed for their beneficial attributes in different production systems. *Crotolaria spectabilis* and *Indigofera hirsuta* produced the highest herbage yields, while *Vigna radiata* had the best cover/spread thus, could be managed for both forage and soil fertility improvement schemes in cropping systems of the Sudano-sahelian regions as shown by Anikwe and Atuma (2003). Good nodulation with high efficiency by most of the species is an indication of effective symbiosis with indigenous strains of rhizobia in the soil. For this study, focus was on implantation and yield attributes. Further studies will be necessary to quantify nutrient input in the soil and uptake by associated crops as well as nutrient content and use by livestock. Their input in the sustainable management of ecosystems and environmental degradation through improved fallows and erosion/runoff management would also be relevant.

Since natural vegetation has proven to be the most effective protector of the soil surface under all forms of exploitation (Klein, 1995; Harmand *et al*, 2003; Donfack *et al*, 1997), it could thus be enhanced with the effective management of these indigenous species in Sudano-sahelian environments to enhance local biodiversity and environmental management goals in a sustainable manner.

Acknowledgement

This work was partly supported by the IRAD/SODECOTON convention with funds from ESA (Eau, Sol, Arbre) project. We are continually grateful. Special thanks to Dr. Awa, D. N. for help in data collection and statistical analysis.

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