Characterizing the Suitability of Selected Indigenous Soil Improving Legumes in a Humid Tropical Environment Using Shoot and Root Attributes

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Summary

We studied the biomass accumulation, root length, nodulation, and chemical composition of roots and shoot of ten indigenous soil improving legumes in a humid tropical ecosystem with the view to selecting species for soil improvement programmes. Two cultivars of Vigna unguiculata*, and one each of* Glycine max*,* Arachis hypogaea*,* Crotararia ochroleuca*,* Cajanus cajan*,* Pueraria phaseoloides*,* Lablab purpureus*,* Mucuna pruriens *and* Vigna subterranea *as treatments were planted in 20 kg pots containing soil from an Oxic paleustalf in Nigeria. The pots were arranged in randomized complete block layout with three replications in a greenhouse at IITA Ibadan, Nigeria. Results from the work show that* M. pruriens *and* C. cajan *produced the highest quantity of biomass. Root elongation was highest in* M. pruriens *whereas* A. hypogaea *produced the most root nodules with native rhizobia. The highest quantity of nodule dry weight was produced by* A. hypogaea *and* P. phaseoloides *whereas most of the legumes except* G. max *and* P. phaseoloides *had high and statistically comparable N content of between 2.36 and 3.34 mg.kg^{-1} N. The results show that the legumes have different root and shoot characteristics, which should be taken into consideration when selecting species for soil improvement programmes.*

Résumé

Utilisation des caractères racinaires et des tiges pour évaluer les aptitudes des légumineuses sauvages amélioratrices du sol dans une zone tropicale humide

Cette étude a été réalisée dans un écosystème tropical au Nigeria sur 10 légumineuses, (deux cultivars de Vigna unguiculata*, et un cultivar de* Glycine max*,* Arachis hypogaea*,* Crotararia ochroleuca*,* Cajanus cajan*,* Pueraria phaseoloides*,* Lablab purpureus*,* Mucuna pruriens *et* Vigna subterranea*), amélioratrices du sol en vue de sélectionner les espèces performantes dans le but de les utiliser dans des programmes de sélection. Les caractères étudiés étaient l'accumulation de la biomasse, la longueur des racines, la nodulation ainsi que la composition chimique des racines et des tiges. L'expérimentation a été effectuée dans une serre de l'IITA, Ibadan, Nigeria. Des pots, remplis de 20 kg de terre d'un sol «Oxic Paleustalf», randomisés en blocs aléatoires complets avec trois répétitions, ont été semés avec ces différentes espèces. Les résultats obtenus montrent que* M. pruriens *et* C. cajan *ont produit la plus grande quantité de biomasse alors que la plus grande élongation racinaire a été obtenue chez* M. pruriens*. Une grande quantité de nodules racinaires, avec les souches de* Rhizobium *local, a été produite par* A. hypogaea *alors que la plus grande quantité de nodules secs a été produite par* A. hypogaea *et par* P. phaseoloides*. La quantité d'azote produite (2,36 et 3,34 mg.kg^{-1}N) était statistiquement élevé et comparable sauf pour les espèces* G. max *et* P. phaseoloides*. Ces résultats montrent que des légumineuses présentent des caractéristiques racinaires et des tiges différentes et que ces caractères peuvent être utilisés dans des programmes d'amélioration des sols.*

Introduction

Pasture and crop legumes have been used extensively in agriculture over the century mainly for maintaining soil fertility (9, 11). As agriculture continues to develop, there are new roles emerging for legumes in the new farming systems**.** Such roles include, the continued expansion of pulse crops into infertile more stressful soils, and the exploration for new genera and species of pasture, forage and soil improving legumes with deep rooting habits for control of soil moisture to combat salinity (5) and retrieve lost nutrients from beyond the soil solum.

The successful use of legumes in these new roles in agriculture will be dependent upon appropriate attention to the formation of effective symbioses with root

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nodule bacteria (8). Apart from forming effective symbioses with root nodule bacteria, legumes selected for use as soil improving legumes should posses some other qualities that will make them adaptable and dependable in the farming system. Some of the qualities include adaptability to local climate and soil type, quick establishment, and ability to colonize an area and to cope with pests and diseases in the local environment. Furthermore, a legume must be able to form its root nodules using the right type of bacteria. In some cases soil microbes of an area may somehow not be compatible with the plant (2). In addition, legumes must persist in the system. To be sure of persistence, the species chosen must be able to set enough seed under the conditions in which it will be used, and this seed must able to survive in the soil so that a seed bank builds up. In this way, new seedlings will always sprout, even after adverse events have weakened or killed mature plants (2). Finally, legumes will help to counteract nitrogen deficiency in the soil. For example, African farms (especially on sub-Saharan-Africa) are currently locked in a downward spiral, in which the traditional bush fallow periods are shortened from 15 or 20 years to as little and two or three (1, 2). Well chosen legumes could supply the nitrogen boost needed for African soils, helping farmers to provide fodder for animals and lift crop yields.

Legumes can circumvent the problems mentioned above if the right species and varieties are selected. Tropical legumes are capable of a large range of uses. They can be integrated into mixed farming systems where they can enhance crop yield (2). Agronomic programmes that target the introduction of legumes into different agro-ecological systems focus initially on the selection of legumes that have the ability to tolerate edaphic constraints that include pest and disease resistance, water stress and tolerance to salinity, acidity and sodicity. Within such selection programme, the interaction of the legume with indigenous soil *Rhizobium* should also be considered. Identifying a range of legumes that could be used in rotation with crops, or intersown with them to improve the productivity of soils is one of the goals of sustainable agriculture.

Rather than work on characterizing and selecting indigenous soil improving legumes for development and use in Africa, most efforts are currently focused on introducing exotic varieties that have been proven in other environments. The result is often mass failures because exotic legumes find it difficult to persist in tropical environments. Thus, current research should be geared towards characterizing and selecting soil-improving legume from a wide range of untapped genetic resources available in the humid tropics especially when this environment holds one of the largest reserves of different kinds of legumes in the world.

The objective of this work was to study the shoot and root characteristics of some indigenous soil improving legumes in a humid tropical ecosystem with the view to selecting species with root and shoot characteristics that will fit into the soil productivity improvement programmes around the humid tropical zone of south-eastern Nigeria.

Specifically, the work will determine changes in root/top ratio with age, determine root length, biomass production, chemical composition of the root and shoot and nodule count and weight of 10 indigenous soil improving legumes.

Material and methods

The study was carried out in the green house of the Resource and Crop Management Division, Soil Fertility Unit of the International Institute for Tropical Agriculture Ibadan, Nigeria. Surface soil (0-15 cm depth) was collected from a plot that has been left fallow for more than two years. The soil was classified as Egbeda series (Oxic paleustalf) and has a sandy loam texture. The soil has the following chemical properties viz. pH-H_20 6.4; organic carbon 1.46 $mg.kg^{-1}$; extractable phosphorus 13.2 $\mu g.g^{-1}$; exchangeable potassium, calcium and magnesium of 0.61, 5.57 and 1.54 $mg.kg^{-1}$ respectively.

The soil samples were air-dried and passed through a 2 mm sieve and thereafter transferred into 2 litre pots each containing 20 kg of soil. In all, 90 pots were used.

Since destructive sampling was to be employed (harvesting was to be done at 30, 60 and 90 DAP), three pots constituted one experimental unit. The experimental units were arranged in a randomized complete block layout with three replications, each containing 10 experimental units. The treatments comprised 10 soil-improving legumes planted to each three-in-one pot. The treatments were: Cowpea – *Vigna unguiculata* (Bauchi Local cultivar), Cowpea – *Vigna unguiculata* (IT86D-719), Soybean – *Glycine max* (TGX 1649-11F), Groundnut – *Arachis hypogaea* (Samnut 16), Crotararia – *Crotararia ochroleuca* G. Don, Pigeon pea – *Cajanus cajan,* Tropical Kudzu – *Pueraria phaseoloides,* Lablab bean – *Lablab purpureus* L., Mucuna – *Mucuna pruriens,* Bambara groundnut – *Vigna subterranea.*

Inorganic fertilizer (NPK 15-15-15) was applied and mixed with the soil at the rate of 100 N-100 P-100 K $mg.kg^{-1}$ of soil before planting. Six seeds per pot in each experimental unit were sown at 0.5 cm depth; this was later thinned down to four seeds per pot after seedling emergence. Weeds were removed by handpicking as soon as they emerged from the pots.

Agronomic measurements made include measurement of plant top dry weight, separation and measurement of fine roots (< 2 mm diameter) and coarse roots (> 2 mm diameter) to determine their dry weight and root length, chemical analysis of the tops and roots for N, P, K, Ca, Mg, C and S content. Except for the chemical analysis, which was done at 90 DAP, all other measurements were made at 30, 60 and 90 DAP.

Harvesting of the species was done at each sampling period. The plants in one pot of each experimental unit were cut at the base of the stem, washed free of soil, put in an envelope, and put in the screen house to dry for 3 days. Thereafter, the samples were transferred to the oven to dry at 65 ^{0}C to a constant weight after which they were weighed. After severing the plant tops, the pots containing the roots were saturated with water in a wash basin and the soil carefully and gradually washed off until the roots were recovered in a wooden (0.2 mm) sieve. The roots were further cleaned in the sieves to remove all debris. Care was taken to avoid loss of the roots. The nodules were counted, put in seed envelopes, labeled, oven-dried at 65 ^{0}C to a constant weight, and then weighed. After collecting the roots, they were preserved in labeled plastic containers in a solution containing 4% formalin as outlined by Meyer and Gottsche (6).

Root size partitioning was also done at the various times of harvest. The roots were removed from the plastic bags and put into glass trays. Tweezers were used to separate them into single units and plant leaves and other debris were removed. Forceps was used to sort out the roots into the two desired sizes (< 2 mm and > 2 mm diameter). These were air-dried, put into seed envelopes and oven dried at 65 ^{0}C, after which the dry weight of each of the sample was recorded. For root length measurement, the modified Tennant method (14) was used. A sub-sample was collected before oven-drying the samples. Grid square sizes measuring 0.5 x 0.5 cm were placed on a table and glass tray placed on top. A little quantity of water was put on the tray to suspend the roots. Then the roots were picked with forceps a little at time, into the tray and then spread on the tray. If the roots were too long, they were cut to smaller sizes of 5 cm or less. With no root lying a top any other, counting was done using a tally counter and bright light for proper illumination. The various intersections on the grid square size were counted vertically first, then horizontally and then summed up. Fine roots and coarse roots were counted separately and multiplied with the appropriate conversion factor as described by Tennant (14). Sub-samples of dried shoot and roots were later ground, sieved with fine mesh and analyzed in the laboratory for nitrogen using the modified macro-Kjeldahl method (3). Available phosphorus was determined by the method of described by Olsen and Sommers (10). Organic carbon was determined using the Walkley-Black procedure (7) whereas Ca, K, Mg and S were determined using the procedures outlined by Dewis and Fretias (4). Statistical analysis of data collected using analysis of variance for a randomized complete block design was carried out according to procedures outlined by Steel and Torrie (13).

Results and discussion

Top biomass production of selected soil-improving legumes at different time scales

Results of the study indicated differences (P< 0.05) in above-ground biomass production of 10 soil improving legumes at 30, 60 and 90 DAP (Table 1).

At 30 DAP, *Lablab purpureus* and *Mucuna pruriens* produced the highest (P< 0.05) above-ground biomass with 26.8 and 25.3 mg.kg^{-1} respectively. These were significantly higher (P< 0.05) than the above-ground biomass produced by legumes with the lowest aboveground biomass (*Pueraria phaseoloides* with 2.6 mg.kg^{-1}, *Cajanus cajan* with 4.5 mg.kg^{-1} and *Vigna subterranea* with 4.7 mg.kg^{-1}) by between 81 and 90%. Similarly, *L. purpureus* and *M. pruriens* had

Table 1
Biomass Production of Selection Improving Legumes at 30, 60 and 90 DAP

	Plant top dry weight (mg.kg^{-1}) DAP			Root dry weight <2 mm DAP			(mg.kg^{-1}) <2 mm DAP			Top/root ratio DAP		
	30	60	90	30	60	90	30	60	90	30	60	90
Vigna unguiculata (Bauchi Local Variety)	19.1	52.3	50.8	2.4	3.54	5.22	0.78	1.67	2.55	5.88	10.03	6.53
Vigna unguiculata (IT86D-719)	13.2	82.2	114.8	1.43	6.88	12.9	0.68	5.46	8.82	6.23	6.66	5.29
Glycine Max	13.6	81.6	65.5	2.47	10.68	11.25	0.72	4.77	4.39	4.26	5.28	4.19
Arachis hypogaea	9.4	73.2	83.7	1.30	7.99	11.33	0.34	1.10	0.75	5.70	8.05	6.93
Crotararia ochroleuca	7.4	63.4	137.2	1.39	7.70	19.20	0.49	3.20	5.43	3.95	5.81	5.57
Cajanus cajan	4.5	50.0	120.8	0.7	7.41	24.5	0.28	2.32	7.85	2.99	5.13	3.72
Pueraria phaseoloides	2.6	59.0	130.6	0.24	9.26	23.0	-	0.80	3.28	10.95	5.86	4.97
Mucuna pruriens	25.3	113.8	209.5	5.15	15.71	34.26	0.60	1.99	3.79	4.40	6.42	5.50
Lablab purpureus	26.8	84.5	103.5	3.83	5.83	11.27	0.88	1.22	2.43	2.41	11.98	7.55
Vigna subterranea	4.7	26.8	39.6	0.70	4.97	9.30	0.13	0.19	0.32	5.69	5.20	4.11
F-LSD (P> 0.05)	3.5	7.6	22.9	0.69	3.8	6.0	0.70	0.84	4.55	-	-	-

between 28 and 72% higher (P< 0.05) aboveground biomass than *Vigna unguiculata* (Bauchi Local) and *V. unguiculata* (IT86D-719), *Glycine max, Arachis hypogaea* and *Crotararia ochroleuca*. These results indicate that *L. purpureus* and *M. pruriens* establish quickly to form aboveground biomass and can protect the soil as early as possible from raindrop impact energy, excessive impact of sunshine that causes N volatilization and help in soil moisture conservation. The lowest aboveground biomass production was observed in *Vigna subterranea* with 26.8 $mg.kg^{-1}$ and this had 76% significantly lower biomass at 60 DAP (Table 1). At 90 DAP, the highest (P< 0.05) aboveground biomass was recorded in pots that had *M. pruriens* (209.5 $mg.kg^{-1}$). This was higher (P< 0.05) relative to pots planted to *Vigna subterranea* (with the lowest aboveground biomass of 39 $mg.kg^{-1}$) by 81%. These results show that in a soil improvement programme in a humid tropical environment where quick legume establishment and high quantity of aboveground biomass production is the key *M. pruriens* and *L. purpureus* might be the immediate choice. However, in species like *C. cajan*, *A. hypogaea*, *C. ochroleuca* and *V. unguiculata* (IT cultivar) although their initial establishment were not fast, they produced moderately high biomass. According to Snapp *et al.* (12) legumes which combine some grain yield with high root and leaf biomass, thus a low N harvest offers a useful promise of meeting farmers food security concerns and improving soil fertility.

Root biomass of selected soil improving legumes at difference time scales

The results of the study show significant differences in the below ground biomass (root dry weight) of the different soil improving legumes studied (Table 1).

In this study, the roots were partitioned into roots <2 mm in diameter (fine roots) and roots >2 mm in diameter (coarse roots). The results show that finer roots generally had higher below-ground biomass than coarse roots.

At 30 DAP, *M. pruriens* with fine root dry matter weight of 5.15 $mg.kg^{-1}$ had highest root dry matter weight. This was significantly higher than fine root dry matter from *L. purpureus* (3.83 $mg.kg^{-1}$), *G. max* (2.47 $mg.kg^{-1}$) and *V. unguiculata* (Bauchi local) (2.46 $mg.kg^{-1}$) by between 26 and 52%. The fine below-ground dry matter yield was lowest at 30 DAP in *V. subterranea* and *C. cajan* by 86% when compared to *M. pruriens* which had the highest below-ground dry matter weight. At 90 DAP the trend in decreasing fine root dry weight is *M. pruriens > C. cajan > P. phaseoloides > C. ochroleuca > V. unguiculata* (IT cultivar) > *A. hypogaea > G. max > L. purpureus > V. subterranea > V. unguiculata (*Bauchi local*).* Fine roots dry weight was higher than coarse roots dry weight by between 31 - 88% in all the soil improving legumes studied. In all, *V. subterranea* and *A. hypogaea* produced the lowest (P< 0.05) coarse root dry weight (0.82 and 0.75 $mg.kg^{-1}$) respectively. These were lower (P< 0.05) by between 85 - 95% than the legume with the highest coarse root weight [*Vigna unguiculata* (IT cultivar) and *Crotararia ochroleuca*] at 90 DAP. Generally, species that produced higher root volume are more likely to explore the rhizosphere more intensively for nutrients, water, mycorrhizal associations etc. and are able to mat and bind soil particles together thus, reducing rill and interrill erosion on cultivated plots. The results clearly indicate that *M. pruriens, C. cajan* and *P. phaseoloides* produce fine roots profusely.

Root length, number of nodules and nodule dry weight of 10 soil improving legumes

Results show significant differences in root length of both fine roots (<2 mm in diameter) and coarse roots (>2 mm in diameter) (Table 2).

Table 2

Root length, number of nodules per pot and nodule dry weight of selected soil improving legumes at 30, 60 and 90 DAP

	Root length ($m.kg^{-1}$) <2 mm DAP			>2 mm DAP			Number of nodules/pot DAP			Nodules dry weight ($g.kg^{-1}$) DAP		
	30	60	90	30	60	90	30	60	90	30	60	90
Vigna unguiculata (Bauchi Local Variety)	1.05	2.06	2.31	0.17	0.14	0.20	262	415	278	0.12	0.95	0.77
Vigna unguiculata (IT86D-719)	0.16	0.97	2.56	0.23	0.25	0.76	278	540	869	0.64	1.82	2.99
Glycine max	1.42	3.70	3.20	0.10	0.24	0.20	19	714	1407	0.18	3.09	3.56
Arachis hypogaea	0.58	2.70	2.61	0.14	0.13	0.18	602	1894	2309	0.28	0.36	1.01
Crotararia ochroleuca	0.57	2.36	6.10	0.29	0.12	0.47	410	212	1091	0.43	0.83	1.63
Cajanus cajan	0.30	2.64	5.12	0.19	0.20	0.75	88	517	1027	0.043	2.08	3.21
Pueraria phaseoloides	0.23	3.49	5.66	-	0.22	0.61	14	627	1196	0.003	2.80	4.69
Mucuna pruriens	0.89	4.78	17.46	0.08	0.24	1.17	52	323	154	0.42	3.56	2.90
Lablab purpureus	1.16	2.10	2.57	0.17	0.16	0.14	295	216	251	0.34	1.86	1.80
Vigna subterranea	0.27	2.89	2.52	0.16	-	0.12	nd	820	698	nd	0.30	0.75
F-LSD (P> 0.05)	1.05	0.284	0.562	0.96	0.62	0.48	221	621	629	0.19	0.79	0.96

At 30 DAP, *G. max, L. purpureus* and *V. unguiculata* (Bauchi local) with 1.42, 1.16 and 1.05 $m.kg^{-1}$ had the highest root length. These were significantly higher (P> 0.05) than the root length measurement from the pots planted to *V. unguiculata* (IT cultivar), *P. phaseoloides*, and *V. subterranea* by between 80 - 89%. The results show that the legume species with the longest initial roots (at 30 DAP) were not the species with the longest roots at 60 DAP. Except for *G. max*, *A. hypogaea* and *V. subterranea* with root lengths lower at 90 DAP when compared to 60 DAP, all the other species had higher fine root lengths at 90 DAP when compared to root length at 60 DAP. *M. pruriens* with 17.5 m fine roots had 86% more fine root length than *V. unguiculata* (IT Cultivar) which produced the lowest fine root length. At 30, 60 and 90 DAP, fine roots were longer than the coarse roots. Higher root elongation in *M. pruriens, G. max, C. cajan* and *P. phaseoloides* means that they can explore a wider soil volume to collect nutrients and possibly recycle nutrients presumably lost beyond the soil solum.

Results show that *A. hypogaea* and *C. ochroleuca* produced the highest (P< 0.05) quantity of nodules per pot (602 and 410 respectively) at 30 DAP. These varieties produced between 95 and 98% more nodules per pot than *P. phaseoloides,* and *G. max* which produced the smallest quantity of nodules (14 and 19 nodules per pot respectively) at 30 DAP. At 60 DAP, *A. hypogaea* had significantly higher (P> 0.05) number of nodules per pot when compared to other varieties. However, although *G. max* and *P. phaseoloides* had the lowest (P< 0.05) nodule number at 30 DAP, they were among the species with the highest (P< 0.05) nodule number at 60 and 90 DAP. These results show that if ploughing-in of legumes as green manure is the aim of planting soil-improving legumes, selected species should be ploughed-in after 60 DAP. But when legumes are planted as relay crops, species like *A. hypogaea*, *C. ochroleuca* and *L. purpureus* which produce biomass and nodules early should be selected for the benefit of the concurrent and subsequent crops. At 90 DAP, *A. hypogaea*, *G. max, C. cajan, C. ochroleuca* and *P. phaseoloides* produced significantly higher (P< 0.05) number of nodules (more than 85%) relative to nodule number per pot in pots of the legumes with the least number of nodules per pot. On the other hand, variation in nodulation amongst the cultivars may reflect their different capacities for growth under the environmental and edaphic conditions studied (15).

The highest nodule dry weight per pot was found in *V. unguiculata* (IT cultivar). This had between 46 and 95% significantly higher (P> 0.05) nodule dry weight than *V. unguiculata* (Bauchi local), *G. max* and *P. phaseoloides* which had the lowest nodule dry weight per pot at 30 DAP. Although, *A. hypogaea* had the highest number of nodules, it did not coincide with the legume that had the highest nodule dry weight (*P. phaseoloides*). This may be because nodule weight appears to relate more to nodule size than number of nodules. The results show differences in nodules number and weight between different legume species and at different stages of legume growth. According to O'Hara *et al.* (9), a key feature of the symbiotic relationship between root nodule bacteria and legumes is the very high degree of specificity shown for effective nodulation of a particular host legume by a strain/species of root nodule bacteria. In this case, selecting a genotype able to nodulate effectively with indigenous root nodule bacteria would be the simplest approach for successful introduction of the legumes. For species of legumes that had low number of nodules [*V. unguiculata* (Bauchi local) *M. pruriens* and *L. purpureus*], it might be that there were little or in some cases no background population of root nodule bacteria in the soil that were able to nodulate the particular host legume. More often noted O'Hara *et al.* (9) uninoculated legume form variably effective root nodules indicating the presence of a population of ineffective or variably effective root nodule bacteria. In this case, the solution is to select the legume crop that forms effective association with indigenous rhizobia adapted to the edapho-climatic conditions of the environment.

Chemical composition of above- and below-ground biomass of 10 soil improving legumes

There were significant differences (P< 0.05) in the chemical composition of the biomass of the different legumes studied (Table 3).

The N content of the above- and below-ground biomass of the different legumes differs slightly by between 3 and 25%. Legume species like *V. unguiculata* (Bauchi local), *V. unguiculata* (IT cultivar), *C. cajan* and *P. phaseoloides* had higher above-ground N content than below-ground N content whereas the other species had more below-ground N content in their biomass. The results show that above-ground biomass of *V. unguiculata* (Bauchi local), *V. unguiculata* (IT cultivar), *C. ochroleuca*, *C. cajan* and *A. hypogaea* with 3.34, 3.16, 2.83, 2.93 and 2.76 N $mg.kg^{-1}$ respectively were not significantly different (P< 0.05). However, they were significantly higher (P< 0.05) than the N content of above-ground biomass of *G. max* and *M. pruriens* which had the lowest above-ground N content, by between 22 and 36%. With the exception of *G. max* and *V. unguiculata* (IT variety) with low (P< 0.05) 2.26 and 2.36 $mg.kg^{-1}$ N content of the below-ground biomass, all other legumes studied had between 3.0 and 2.61 $mg.kg^{-1}$ below-ground biomass N which were not significantly different. Although, *V. unguiculata* (Bauchi, local) had low above- and below-ground biomass (Table 1), it had higher (P< 0.05) N content in its above-ground biomass than species with higher biomass content. However, production of more biomass may lead to higher overall N contribution. For example, for selection purposes, the low biomass N from *M. pruriens* and *P. phaseoloides* may have been compensated for by high biomass production and nodulation ability.

Results also show that above-ground biomass P was significantly higher (P< 0.05) in *V. unguiculata* (Bauchi local) (0.32 $mg.kg^{-1}$) and *V. subterranea* (0.28 $mg.kg^{-1}$) by 34 - 47% relative to other legumes used. No signifi-

Table 3

Chemical composition of plant top and roots of selected soil improving legumes at 90 DAP

	N		P		C		Ca (mg.kg-1)		K		Mg		S	
	Top	Root	Top	Root	Top	Root	Top	Root	Top	Root	Top	Root	Top	Root
Vigna unguiculata (Bauchi Local var.)	3.34	3.21	0.32	0.09	39.8	42.6	3.07	1.90	2.76	0.06	0.73	0.38	0.47	0.39
Vigna unguiculata (IT86D – 719)	3.16	2.36	0.21	0.05	41.5	41.9	3.46	1.37	1.60	0.07	0.72	0.33	0.30	0.21
Glycine max (TG 1649 - 11F)	2.15	2.26	0.18	0.02	42.4	43.0	2.70	0.91	1.12	0.02	0.89	0.18	0.23	0.21
Arachis hypogaea	2.76	2.90	0.19	0.05	42.4	42.9	2.86	1.64	2.15	0.02	0.82	0.29	0.33	0.30
Crotararia ochroleuca	2.83	2.68	0.17	0.05	43.5	40.8	1.37	1.37	1.71	0.04	0.72	0.28	0.28	0.23
Cajanus cajan	2.93	2.67	0.20	0.05	44.7	44.4	1.59	1.34	1.56	0.03	0.48	0.24	0.33	0.24
Pueraria phaseoloides	2.47	2.61	0.21	0.04	42.8	42.6	2.72	1.32	1.18	0.03	0.57	0.30	0.29	0.25
Mucuna pruriens	2.25	2.96	0.17	0.05	44.0	41.2	2.24	1.50	1.04	0.02	0.50	0.27	0.23	0.29
Lablab purpureus	2.64	2.89	0.17	0.05	42.5	41.5	1.87	1.93	2.05	0.06	0.47	0.31	0.30	0.32
Vigna subterranea	2.53	3.00	0.28	0.12	40.2	42.3	6.46	1.69	1.25	0.05	0.57	0.32	0.62	0.32
F-LSD (P> 0.05)	0.44	0.44	0.07	0.02	1.22	0.70	0.38	0.40	0.42	0.03	0.08	0.08	0.08	0.08

cant differences were found between the above-ground biomass P of other legumes used. Although, the below-ground biomass P of the legumes were lower by up to 72% in some cases, the results follow the same trend as above-ground biomass.

The carbon contents of both the above- and below-ground biomass of all the legumes were similar. However, *C. cajan* and *M. pruriens* (with 44.7 and 44.10 mg.kg^{-1} C respectively) had significantly higher above-ground biomass C and this was higher ($P< 0.05$) by 10% than the legumes with the least above-ground biomass carbon *V. unguiculata* (Bauchi, local) and *Vigna subterranea.* Calcium content of the above-ground biomass was higher than that of the below-ground biomass by between 1.2 to 3.0 fold. The highest Ca content of both the above- and below-ground was found in *V. unguiculata* (IT cultivar) which had Ca content of 3.46, 3.07 and 3.46 mg.kg^{-1}. For K and Mg, higher quantities of these elements were found in the above-ground biomass when compared to the below-ground biomass. Similar quantities of S were found both in the above- and below-ground biomass of the different legumes with *V. subterranea* and *V. unguiculata* having significantly higher S content relative to *G. max* and *M. pruriens* which had the lowest above-ground biomass S. Based on overall suitability of the legumes as soil improving legumes and considering only shoot and root characteristics (Table 4), results indicate that *M. pruriens* and *C. cajan* had the highest ratings (15 and 14 respectively) for overall suitability based on shoot and root characteristics.

Table 4

Ranking of 10 indigenous legumes according to their suitability as soil improving legumes using root and shoot characteristics

	Plant top dry wt.	Root dry wt.	Root length	Number of nodules	Nodule dry wt.	Nitrogen content	Total score
Vigna unguiculata (Bauchi Local)	*	*	*	*	*	***	8
Vigna unguiculata (IT86D – 719)	*	**	*	*	**	***	10
Glycine max	*	*	*	**	***	*	9
Arachis hypogaea	*	*	*	***	*	***	10
Crotararia ochroleuca	**	**	*	**	*	***	11
Cajanus cajan	***	***	*	**	**	***	14
Pueraria phaseoloides	**	**	*	**	***	**	11
Mucuna pruriens	***	***	***	**	**	**	15
Lablab purpureus	**	*	*	*	*	***	9
Vigna subterranea	*	*	*	*	*	***	8

NB The ranking was derived from the highest and lowest values of the different parameters in this work. The values were normalized into three representing high ***, medium ** and low *.

These were higher than the rating for *C. ochroleuca*, *P. phaseoloides, V. unguiculata* (IT cultivar) by 21% whereas *Vigna unguiculata* (Bauchi local) and *V. subterranea* had the lowest rating of 8 respectively. From the results of the work and the rating scale used, the overall suitability based on root and shoot characteristics, is thus *M. pruriens* > *C. cajan* > *C. ochroleuca* > *P. phaseoloides* > *A. hypogaea* ≥ *V. unguiculata* (IT cultivar) > *G. max* ≥ *L. purpureus* > *V. subterranea* ≥ *V. unguiculata* (Bauchi local).

Conclusion

The results of this study have shown that different species of legumes have different characteristics, which should be considered in selecting species for soil improvement. In this study, *C. cajan* and *M. pruriens* produced more above- and below-ground biomass than other legumes studied. Also, *A. hypogaea*, *C. cajan*, *G. max*, *P. phaseoloides* and *M. pruriens* produced moderate to high number of nodules whereas only *A. hypogaea* and *P. phaseoloides* had high nodule dry weight per pot. The N content of the biomass of all the soil improving legumes were high save for *G. max* and *P. phaseoloides* which had lower N content. Finally, the results show that overall ranking of the attributes studied indicate that *M. pruriens* and *C. cajan* had better shoot and root characteristics as soil improving legumes for use in the tropical humid environment of the area studied.

Finally, the choice of any legume as soil improving legume and the combination of functions relevant in one situation will depend on the particular conditions of the site (climate, soil, slope), the farming activities, (crop, livestock) and the value of inputs to the farming system (land, labour, agrochemical, cash).

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Literature

1. Anikwe M.A.N., Mbah C.N. & Umeh G.N., 2000, On farm soil and water conservation technology in Abakaliki area, southeastern Nigeria. Nigerian Journal of Soil Science, 12, 12-21.
2. Beckmann R., 2002, Legumes offer a ray of hope in southern Africa. Partners in Research for Development. Nº 15, May 2002. Australian Centre for International Agricultural Research.
3. Bremner J.M. & Mulvaney C.S., 1982, Nitrogen-total. *In*: Page A.L., Miller R.H. & Keeney D.R., eds, Methods of soil analysis, Part 2, chemical and microbiological properties. Madison, WI, American Society of Agronomy, 595-624.
4. Dewis J. & Fretias F., 1970, Physical and chemical methods of soil and water analysis. Soil Bulletin Nº 10, FAO, Rome.
5. Howieson J.G., O'Hara G.W. & Carr S.J., 2000, Changing roles for legumes in Mediterranean agriculture: developments form an Australian perspective. Field crops Research, 65, 107-112.
6. Meyer F.H. & Gottsche D., 1971, Distribution of root tips and tender roots of beech. Integrated Experimental Ecology, 7, 48-52.
7. Nelson D.W. & Sommers L.E., 1982, Total carbon, organic carbon, and organic matter. *In*: Page A.L. (eds), Methods of soil analysis, Part 2, chemical and microbiological properties 2nd ed. Agronomy series Nº 9. ASA, SSSA, Madison, WI, USA.
8. O'Hara G.W., Yates R. & Howieson G.J., 2001, Selection of traits of root nodules bacteria to improve inoculant performance and increase legume productivity in stressful environments. *In*: Herridge D. (eds), Inoculants and nitrogen fixation of legumes in Vietnam, ACIAR Proceedings Nº 109e. Pp 75-80.
9. O'Hara G.W., 1998, The role of nitrogen fixation in crop production. Journal of Crop Production, 1, 115-138.
10. Olsen S.R. & Sommers L.E., 1982, *in*: Page A.L., Miller R.H. & Keeney D.R., Eds, Methods of soil analysis, Part 2, chemical and microbiological properties, 403-448.
11. Slattery J. & Pearce D., 2001, The impact of background rhizobial populations on inoculation response, *in*: Herridge (eds), Inoculates and nitrogen fixation of legumes in Vietnam. ACIAR Proceeding Nº 109e pp 37-45.
12. Snapp S.S., Mafonyoga P.L. & Waddington S., 1999, Organic matter technologies for integrated nutrient management in small holder cropping systems of Africa. Agriculture, Ecosystem and Environment, 71, 187-202.
13. Steel R.G. & Torrie J.H., 1980, Principles and procedures of statistics: A biometric approach 2nd edition, McGraw-Hill, New York.
14. Tenannt D., 1975, A test of a modified line interest method of estimating root length. Journal of Ecology, 63, 995-1001.
15. Thao Y.T., Singleton P.W. & Herridge D., 2001, Inoculation responses of soybean and liquid inoculants as alternative to peat-based inoculants. *In*: Herridge D (eds), Inoculants, and nitrogen fixation of legumes in Vietnam. ACIAR Proceedings Nº 109e. Pp 67-74.

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