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Influence of Soil Fertility Management Practices on the Nodule-forming Ability of Some Soybean Varieties in a Sub-humid Environment, Nigeria

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Abstract

In a two-year field trials, the influence of eight soil fertility management practices in optimizing the ability of six selected promiscuous soybean varieties to form nodules was evaluated in Abakaliki, Southeastern Nigeria which has no history of soybean cultivation in the past. Soil test before planting indicated a pH of 5.50 and 5.85 after harvesting with high available phosphorus, which may have been the reason for its low impact in influencing nodule formation among other practices. Poultry manure and wood ash were both affordable and available low-external inputs which had high potentials in improving and optimizing nodule formation in the soybean varieties to 73.14% and 50.92% in 2008 and 68.55% and 30.77% in 2009, and both are highly recommended as veritable tools for improving soil fertility among the smallholder farmers, where high cost of external inputs has always been the major setback to crop production.

Keywords: Inorganic fertilizer, nodule formation, poultry manure, promiscuous soybean, soil fertility

1. Introduction

A major key factor controlling the efficiency of biological nitrogen fixation technology (legume N_2 fixation) is the ability of the legume plants to form effective root nodules in association with compatible available rhizobium population in a given area, which in turn depends to a large extent on the legume species, soil conditions and soil fertility management systems practiced. In many soils of the tropics the populations of the native (naturalized) rhizobia are not sufficient to induce nodule formation in the sown legume which may require inoculation with the right strains or allowed to build up over time through continued cultivation of the right legume host (Giller and Wilson, 1991, Hardarson and Atkins, 2003, Leinonen, 1996). About 100 million t N, valued at $US50 billion, is required annually for the production of the world's grain and oilseed crops, of which 20% (17 million t N) can be supplied by the food legumes to save $US8.5 billion if N fertilizer sells at the rate of $US0.50/kg (Herridge, 2002). Of all the herbaceous, shrub and tree legumes, soybean has indeed become a benchmark nodule-forming legume, second only to the stem-nodule forming Sesbania rostrata (Rinaudu et al., 1983), making biological nitrogen fixation technology the rate determining step in food production (Postage, 1970), and corollary a significant option for replenishing the fragile soil systems of Africa than inoculation technology (Giller and Wilson, 1991). Currently Brazil produces 20% of the world's soybeans second to the largest producer USA and saves over US$ 2.5 billion per year in terms of N-fertilizer from biological nitrogen fixation (Alves et al., 2003).

However, during the mid 1900s, technologies to mass-produce plant nutrients became readily available, inexpensive and easy to apply, eliminating the drudgery involved in growing and applying green manures, therefore, became the preferred method for supplying nitrogen to crops in many parts of the world, except for the energy crisis of 1970s. Fertilizer production accounted for about 45% of energy used in agriculture world-wide, while 73% of which is used in the manufacture of nitrogen fertilizer (McCune, 1984). Incidentally, both mankind's factory-made fertilizers and chemical fixation processes (lightning and internal combustion engines); taken together account only for 1 or 2 percent of the total N_2 fixed by microbes (between 100 and 290 million tons of N annually) on global basis (Cleveland et al., 1999).

The agro-forestry system which approximates the traditional shifting cultivation served as an alternative, in which the trees can sequester 5 to 10 times more carbon per hectare per year than most other farming systems in the world (Sanchez, 2001) but suffered low acceptance to great many smallholder farmers (Giller, 2003), because it could not fulfill the direct and indirect benefits to them such as food, fibre, fodder and fertilizer beyond simply improving soil fertility (Misiko, 2007) as well as being responsive to the emerging challenges (Catacutan et al., 2001). The selection of legume species should be those that are ecologically and economically relevant to the smallholder farmers who use it (Moreira et al., 2009). Soil organic matter (SOM) is closely related to soil fertility and has an impact on physical, chemical and biological properties of the soil (WOCAT, 2007). For the foreseeable future, therefore, dealing with poverty and hunger in much of the world means confronting the problem the smallholder farmers and their families face in the daily struggle for survival (Dixon et al., 2001).

Research shows that the rate of nitrogen fixation is dependent on the vigour of the plant, efficiency of the rhizobia and environmental conditions, and that the variations observed in the success of biological nitrogen fixation (BNF) in most tropical countries were due to low population of compatible and effective indigenous strains of rhizobium in the soil, use of unsuitable strains of inoculants, inability of introduced strains to displace or replace the indigenous rhizobia, environmental management factors (low pH, calcium and phosphorus, high aluminum and manganese, water stress (low or high), temperature, N-availability) and plant vigour (Leinonen, 1996; Ledgard and Giller, 1995; Singleton et al., 1990). Also important is the observation that the requirements of one symbiotic partner closely parallel those of the other and corollary the conditions which adversely affect the growth of plant roots in tropical soils also inhibit nodulation (Giller, 2003, Broughton, 1981).

Incidentally, the formulation, production and delivery of viable and suitable inoculants for a crop species at the time of sowing is exacting (Hardarson and Atkins, 2003; Stephens and Rask, 2000), but, it is possible in response to the presence of the right host plant where soil conditions are favourable to increase the number of compatible native bacteria over a few seasons. However, little is known of the rate and time of proliferation within any agronomic practice since nitrogen is fixed only after rhizobia have invaded legume roots and produced nodules. This unique attribute is not always efficiently exploited in developing countries, therefore, managing the soil adequately for effective native rhizobium build-up in the host legumes efficiently and enhanced legume growth, yield and nitrogen fixation sufficiently in the farmer's plot without inoculation is an excellent option for the future (Giller and Wilson, 1991) by using promiscuous soybean cultivars in developing countries.

Among the prodigious legume plants providing a wide range of products, protein for the majority of the world's poor; vegetable oil, animal fodder, poles, fuel wood and enhancement of soil fertility (Giller, 2003, Sarrantonio, 1991, Broughton, 198l), the pulses especially the soybean is most important but requires good growing conditions to ensure vigorous growth that enables it provide enough energy for the rhizobium to form effective root nodules. Its 'fertilizer replacement value' is quite high (Thiessen-Martens et al. 2005) and has been estimated to fix 80 million tons of nitrogen annually from the vast supply in the air (FAO, 1984). Soil quality, soil organic matter, soil structure or tilt, soil water and nutrient holding and buffering capacity of soils, soil carbon sequestration are all improved (Patrick et al., 1957, Kuo et al., 1997, Sanju et al., 2002, Lal, 2003), while soil erosion and soil porosity are checked to provide suitable habitat networks for soil macro fauna as risk of toxic build up is minimized (Tomlin et al., 1995) by legumes. Against this background, the objective of this experiment was to determine the influence of eight soil fertility management practices on the number of root-nodule forming ability of six soybean varieties in Abakaliki, Southeastern Nigeria.

2. Materials and Methods

2.1 Site description

The experiment was carried out on the research farm of Faculty of Agriculture and Natural Resources Management (FARM), Ebonyi State University, Abakaliki, Southeastern Nigeria, lying on latitude 06^0 19´ 407´´ N and longitude 08^o 7´ 831´´ E at an altitude of about 447 m above sea level with a mean annual rainfall of about 1700 mm to 2060 mm spread between April and October. The maximum mean daily temperature is between 27^o C to 31^o C with abundant sunshine and a high humidity all through the year. The soil is shallow with unconsolidated parent materials (shale residuum) within 1m of the soil surface, described as Eutric Leptosol (Anikwe et al., 1999). Soil samples from the experimental plot were collected and analyzed before planting and after harvesting in 2008 and 2009 planting years.

2.2 Land preparation

Clearing and raised-bed making were manually carried out. Clearing was essentially slashing of new weed flushes resulting from the usual annual uncontrolled bush fire to which the research plots were often subjected to. From a randomization device such as numbered paper cards, lime, wood ash and poultry manure were applied to the designated plots during bed making and were allowed two weeks to infuse into the soil before seeds were sown.

2.3 Seed sowing
Two seeds were sown after mild loosening of the soil surface with a hand fork for seeds to germinate and emerge without obstruction at plant spacing of 30 cm x 15 cm (inter- and intra- rows respectively) sown at a depth of about 2-3cm.
2.4 Plot maintenance
Weeds were manually removed as the need arose in each year, 2-3 times and plants were earthen up to prevent lodging of plants and the pods from touching the ground.
2.5 Treatment application
The experiment was an 8 x 6 factorial arranged in a randomized complete block design (RCBD) in four replications. Factor A was eight soil fertility management practices; lime ($CaCO_3$) at 10 tons ha^{-1}, wood ash at 10 tons ha^{-1}, poultry manure at 20 tons ha^{-1}, single super phosphate (SSP) at 40 kg ha^{-1}, urea (N) at 20 kg ha^{-1}, NPK (15:15:15) at 40 kg ha^{-1}, muriate of potash (MOP) at 30 kg ha^{-1} and a control**),** while factor B was six soybean varieties: three early maturing varieties (TGx 1876-4E, TGx 1485-ID, TGx 1903-7F) and three medium maturing varieties (TGx 1908-8F, TGx 1904-6F, TGx 1844-4E). The fertilizers and the lime were sourced from Ebonyi State fertilizer blending plant, Onuebonyi, Izzi Local Government Area. Wood ash was collected from a bread bakery, Nora Foods Industries, Enugu-Ngwo in Enugu State. Poultry manure (PM) was obtained from the Department of Animal Science, Ebonyi State University. Soybean varieties came from the promiscuous series (naturally forming nodules without inoculation) bred by the International Institute of Tropical Agriculture (IITA), Ibadan. 48 treatment combinations were planted out in 192 plots of 1m x 1m separated from one another by 0.5m, while each block (replicate) was separated by 1m pathways. Each plot contains three rows of six plant stands or 18 plant stands per plot out of which four innermost plants from the innermost row of the plots consisted the observational unit from which nodule parameters were measured: number of nodules per plant at flowering, this was done by wetting the soil sufficiently to soften it before uprooting to ensure high percentage nodule recovery and was counted afterwards.
2.6 Statistical analysis
The data collected were subjected to analysis of variance (ANOVA) using a statistical tool, the GenStat Release 7.22 DE (Copyright 2008). Treatment means were separated using Fisher's Least Significant Difference (F-LSD = LSD) as illustrated by Obi (1986) to identify significant treatment effects in the experiments.

3. Results and Discussion
The pH values before planting was 5.50 (2008), while it rose to 5.55 and 5.85 in 2008 and 2009 respectively after harvesting. High available phosphorus (P) was observed in the area before planting (20.00 mg Kg^{-1} in 2008 and after harvesting (22.11 mg Kg^{-1} in 2008 and 24.57 mg Kg^{-1} in 2009) which showed that the application of limes and phosphorus improved their availability according to Lickacz (2002), Sarrantonio (1991), Duong and Diep (1986). Soil test for optimizing input use, sustainable agricultural productivity, improved rural livelihood in the face of declining soil productivity is advocated in view of the rapid population growth as recommended by Munson and Runge (1990), Place et al. (2003). The high level of available P before planting may have led to the non significant response of soybean varieties to P in influencing nodule formation. Elliot et al. (2009) reported that P tends to move down hill across the field and is less likely to leach vertically into the ground water. The use of phosphate fertilizer can produce substantial increases in soybean yields if soil test values for phosphorus are in the low and very low ranges but reduces yields to non significance if soil test values are medium to very high ranges in soils as Rehm et al. (2012) observed in Minnesota soils. The table below was tabulated by Rehm et al. (2012 for phosphate fertilizer application for soybean production in Minnesota

		Phosphorus (P) soil test (ppm)				
		Very low	**Low**	**Medium**	**High**	**Very high**
	Bray:	**0-5**	**6-10**	**11-15**	**16-20**	**21+**
Expected yield	**Olsen:**	**0-3**	**4-7**	**8-11**	**12-15**	**16+**
Bu./acre		**- - - - - - P2O5 to apply (lb./acre) - - - - - -**				
Less than 30		**50**	**30**	**0**	**0**	**0**
30-39		**60**	**40**	**0**	**0**	**0**
40-49		**70**	**50**	**0**	**0**	**0**
50-59		**80**	**60**	**0**	**0**	**0**
60 or more		**90**	**70**	**0**	**0**	**0**

Phosphorus is taken up throughout the growing season and its availability is at maximum level at a pH of between 6.0 and 7.0. Adequate P is essential for optimal crop yields, enables a plant to store and transfer energy, promotes root, flower and fruit development and allows early maturity in plants (Elliott et al., 2009) The period of greatest demand starts just before the pods begin to form and continue until about 10 days before the seeds are fully developed. Much P used in seed development is taken up early, stored temporally in leaves, stems and petioles, and then trans-located into the seed. Stunted growth is usually the only symptom of P deficiency, though some leaf cupping and discolouration are possible. 1 ton of soybean seed removes 5kg of P, compared with 3kg P for maize. Being a lower yielder, soybeans would remove 70% of the P contained in a maize grain crop. Soil test norms for P should be the same as maize. Soil with medium or low levels of P should receive 20-40 kg/ha of P respectively. Optimum P for loam soil is 22 mg/litre and 12 mg/litre for clay. P tends to move downhill across the field and is less likely to leach vertically into the ground water. On alkaline soils research shows that it is best to use composted or vermin-composted manure to minimize environmental impacts (Elliott et al., 2009).

Table1: Some soil physical and chemical properties of the experimental area before planting and after harvesting

	2008		2009	
Chemical analysis	Before	After	Before	After
pH (H2O)	5.50	5.55	5.50	5.85
% Total N	0.14	0.18	0.15	0.20
Available P mgKg-1	20.00	22.11	19.00	24.57
% Organic carbon	1.64	1.01	1.29	1.12
% Organic matter	2.83	1.74	2.22	1.93
Exchangeable cat ions (cmol-kg-1)				
Calcium (Ca)	3.00	2.75	2.60	2.36
Magnesium (Mg)	1.60	1.65	1.70	1.72
Potassium (K)	0.13	0.15	0.16	0.18
Sodium (Na)	0.21	0.20	0.20	0.20
Soil particle analysis (%)				
Sand	64.50	63.50	65.00	64.60
Clay	25.00	25.00	26.00	25.50
Silt	11.00	11.02	11.01	11.04
Texture	Sandy loam	sandy loam	sandy loam	sandy loam

Analytical laboratory of the National Root Crops Research Institute (NRCRI), Umudike with soil samples collected at 15cm and 30cm depths (bulked) and air dried before the analysis

Table 2 displays the variety x soil fertility management practices interaction on nodule formation. The soil fertility practices significantly (P=0.05) increased the number of nodules per variety except in year one. Nodule formation in legumes is an important index in the biological nitrogen fixation (BNF) technology of which soybean is the bench mark nitrogen fixing legume after stem-nodule-forming legumes (Ludwig, 1989). With the number of nodules produced by the six varieties as influenced by the treatments in the two season plantings, the mean number of nodules in the varieties was strikingly low in comparison with the observations of Ndaeyo et al. (2000) who reported a range of 22.9-69.3 (1990 planting) and 24.3 to 79.0 (1991 planting), which may be explained on the bases of location and/or varietal differences. However, it is expected that with more years of cultivation, the number will appreciate (Singleton, 1990) because the population of the native rhizobium will likely increase as proposed by Leinonen (1996) and it did increase as indicated in the mean number of nodules recorded in the second year and years combined among the varieties. TGx1876-4E and TGx1485-1D were the highest with 10 and 11 nodules each in 2008, while in the second year 2009, the least number was 11 nodules from TGx1844-4E and TGx1904-6F with other varieties having 14-15 nodules to justify the prediction of Leinonen (1996).

Agricultural lime (e.g. $CaCO_3$) is a veritable tool used to render acid soils fertile effectively because it increases its alkaline status (high $_{P}H$) which increases the activity of the nitrifying bacteria that favour nodule formation and decreases the activity of the denitrifying bacteria which prefer an acid soil (low $_{P}H$). Apart from poultry manure (PM) with 25.25 nodules per plant, wood ash and agricultural lime influenced higher number of nodules (12.44 and 10.58) than other fertilizer practices in the years combined and in separate years. This result clearly indicates that if agric lime proves to be a costly external input, a low or nearly costless but effective and better substitute like woodash (which had up to 15 nodules per plant in two varieties in 2008) can be used to improve nodule formation of the varieties that showed high response to agric lime application (between 10-12 nodules per plant in 2008).

Acid soils have been recognized as one of the major limiting factors to the production of legumes and many other crops (acidity fixes most soil nutrient elements), hence liming is required on the soil surface for optimum or maximum yields (Duong and Diep, 1986, Lickacz, 2002). Lime is applied to acid soils to neutralize excess acidity (very low pH) that causes reduced crop yields, thus lime raises the soil pH to make the soil more productive in several ways: 1) Liming removes aluminum and iron toxicity to growing plants by making them insoluble. 2) Keeps phosphorus of the soil and in applied phosphates available over a longer period. 3) Calcium salts promote flocculation or granulation hence limestone improves soil structure, better aeration and water relationships and making it a more suitable place for plants to grow. 4) Liming increases the activity of nitrogen fixing organisms, hence an important practice in legume production. 5) Liming promotes more rapid decay of manure and crop residue in the soil, thus making their elements available more quickly to plant life.

However, despite the low number of nodules recorded in this experiment, it is important to note that PM influenced the highest number of nodules among the varieties in both years with TGx 1908-8F producing the highest number in the second year (40.75), while the highest in year one was TGx1844-4E. Rhem et al. (2012) also observed that because of concerns for environmental quality, the use of livestock manures to fields planted to soybean crop is being encouraged, which Khaliq (2004) observed was a good way of growing corn in an environment-friendly systems. Singleton (1990) observed that if the plants have had a good growth, then high number of nodules was possible. The number of nodules produced by poultry manure in year one was 29.54 and 20.96 in year two. It is expected that with subsequent cultivation, soybean will attract and host the right native rhizobium population that may induce more number of nodule formation (Leinonen, 1996).

Table 2: Variety x soil fertility management practices interaction on the number of nodules per plant of soybean variety.

				2008					
				Treatment					
Variety	Wood ash	Control	Lime	MOP	NPK	PM	SSP	Urea	Mean
TGx1876-4E	8.75	6.00	10.50	8.00	8.25	22.75	6.25	9.50	10.00
TGx1903-7F	14.50	1.50	6.00	3.75	6.50	21.00	2.25	9.25	8.09
TGx1485-1D	14.75	10.00	13.25	4.75	8.50	18.75	8.25	8.50	10.84
TGx1844-4E	6.50	2.75	9.75	5.75	8.25	24.00	5.00	8.00	8.75
TGx1904-6F	7.50	8.50	12.00	5.50	4.00	19.00	3.75	5.25	8.19
TGx1908-8F	10.50	5.00	12.00	5.50	5.50	20.25	3.00	7.25	8.63
Mean	10.42	5.63	10.58	7.42	8.42	20.96	5.71	9.92	
F-LSD (P=0.05) =2.02 for comparing two variety means =2.33 for comparing two fertilizer means =5.72 for comparing variety x treatment interaction means									
				2009					
TGx1876-4E	14.25	14.50	17.50	10.50	8.25	33.50	10.25	10.75	14.94
TGx1903-7F	20.50	5.50	6.75	14.50	10.75	28.00	12.25	12.75	13.88
TGx1485-1D	18.00	10.75	16.25	14.25	10.75	26.50	8.00	12.00	14.56
TGx1844-4E	7.25	5.50	5.25	7.25	14.00	27.50	9.50	11.00	10.91
TGx1904-6F	14.75	5.00	7.75	10.50	13.50	21.00	5.50	10.50	11.06

TGx1908-8F	12.00	14.50	10.00	10.25	8.25	40.75	7.00	10.70	14.18
Mean	11.46	9.29	8.92	9.33	9.33	29.54	7.79	9.42	

F-LSD (P=0.05) =1.30 for comparing two varietal means
=1.50 for comparing two treatment means
=3.68 for comparing variety x treatment interaction means

2008 and 2009 Combined

TGx1876-4E	11.50	10.25	14.00	9.25	8.25	28.12	8.25	10.12	12.47
TGx1903-7F	17.50	3.50	6.37	9.12	8.63	24.50	7.25	11.00	10.98
TGx1485-1D	16.38	10.38	14.75	9.50	9.63	22.62	8.12	10.25	12.70
TGx1844-4E	6.88	3.25	7.50	6.50	11.12	25.75	7.25	9.50	9.72
TGx1904-6F	11.12	6.75	9.88	7.50	8.00	20.00	4.00	7.88	9.39
TGx1908-8F	11.25	9.75	11.00	7.88	6.88	30.50	4.00	9.25	11.31
Mean	12.44	7.31	10.58	8.29	8.75	25.25	6.48	9.67	

F-LSD (P=0.05) =1.43 for comparing two varietal means
=1.36 for comparing two treatment means
=3.39 for comparing variety x treatment interaction means

Table 3 is a summary of the general outlook of the effect of the treatments on the number of nodule formation in the varieties in the area, which depicted poultry manure (PM) as the best tool for improving nodule formation with 29.54 nodules at first trial (2008), followed by wood ash (13.42), lime (12.25), Urea (9.92), NPK (15:15:15) (8.42), K_2O (7.42), the control (5.63) and P_2O_5 (5.71). The low number of nodules recorded under phosphorus is very strange and not in consonance with Singleton et al. (1990) who maintained that lack of P limits plant growth while a limited growth limits nodule formation. Perhaps, the poor influence of P on number of nodules could be explained on the basis of what appears as over dose of P, but Elliott et al. (2009) did not indicate that problem, though, they suggested optimum P for loam soil, 22 mg/litre and 12 mg/litre for clay. However, it is established that P does not limit growth of soybean in Abakaliki and that PM improves the growth of soybean hence, it is suitable for the farming practice in this area. According to Rehm et al. (2012), livestock manure is an excellent source of phosphorus (P), potassium (K), all secondary nutrients and the micronutrients.

However, organic manures have the disadvantage of taking a little longer to break down in the soil but have the potential to improve the soil structure, increase the ability of soil to hold both water and nutrients and the risk of toxic build up is minimal. Concerns for environmental quality have necessitated the use of livestock manures in fields planted to soybean crop rather than applying excessive amounts on lands where maize is grown and such manures are excellent sources of nitrogen (N), phosphorus (P), potassium (K), all secondary nutrients and the micronutrients (Rehm et al., 2012). Organic P fertilizers come from animal manures including, compost and sewage sludge (Rehm et al., 2012). Generally chicken (poultry) manure is the best, followed by goat manure while cattle manure is of lower quality (ICRISAT/MAI, 2000).

Soybean, being a legume fixes adequate atmospheric N to produce yields of 3000-4000kg /ha, if nodules formed well. Johnson et al. (1975) found that adding N to well nodulated soybeans produced no yield increase. Fertilizer N added at planting delays nodulation. This may be the reason urea had no significant effect on the number of nodules among the varieties used. Gascho et al. (1989) suggested that N application during the vegetative stages result in decrease in nodulation in proportion to the rates applied. Adding N is recommended only when adequate nodulation is not expected. 1 ton of soybean seed removes 6okg of N by the plant, or about 270kg N for a 3-ton seed crop. No N need be applied if the crop is well inoculated with bacteria. Where inoculation is poor N fertilizers should be applied at the same rate as maize (Smith, 2006). N deficiency results in reduced chlorophyll development (pale-green leaf), growth and yields.

Potassium (K) is relatively required in large amounts. It could be that the rate applied in this experiment was not adequate to bring about more number of nodules than was recorded. It has been reported that the rate of uptake is highest during rapid vegetative growth and slows as seed formation begins, showing that split application might improve the number of nodules formed. This is because uptake is continuous until two to three weeks before the seed is mature, it can be depressed by poor soil condition including compaction, excess moisture and poor aeration. Most K taken up, moves to the roots by diffusion through moisture films around soil particles. As the water contents of a soil decreases, moisture films around the soil particles become thinner and the path length of ion movement increases and the movement of K to roots decreases. K uptake is reported to decreases if the oxygen content of the soil is low, therefore poor aeration would require higher available K, while cold soils reduce the rate and extent of root growth and this can limit K uptake. When farmers plant earlier or adopt tillage practices that result in lower soil temperature early in the growing season, such as no-till, higher levels of available K in the soil are likely to be needed for optimum growth (Yin and Vyn, 2001; Isherwood, 2006; Magen, 2007). 1ton of soybeans contains 18kg of K compared with 3.5 kg K for maize grain and will remove twice the amount of K as maize grown under similar conditions, i.e. 5 tons of maize compared with 2 tons of soybeans. Soybeans have a lower soil test requirement than maize, with 80 mg/litre being the critical level. Soils with medium or low levels of K should receive 30-60kg/ha of K. K deficiency is easily recognized; chlorosis starts along the outside edges of leaves, especially the older leaves.

Wood ash has beneficial effect on crop growth as an alternative to lime and/ or to the use of acidity tolerant crops has been documented (Duong and Diep, 1986, Spore, 1995, Lickacz, 2002), as it contains the oxides and hydroxides of calcium, magnesium, potassium and to a lesser extent sodium making it similar to burned or hydrated lime in its mode of action (Lickacz, 2002). It is used to supply calcium in groundnut plots showing calcium deficiency (Spore, 1995). Many factors contribute to soil acidity such as, acidic rock parent materials, leaching, crop removal at harvest, use of nitrogen fertilizers, decomposition of soil organic matter, plant root and organism respiration, presence of deciduous and coniferous vegetative cover and absorption of carbon dioxide and sulphur directly from the atmosphere.

Table3: Effects of soil fertility management practices on the number of nodules in six soybean varieties

Treatment	2008	Difference	2009	Difference	Combined years
Wood ash	11.46	5.83	13.42	4.13	12.44
Control	5.63	0.00	9.29	0.00	7.31
Lime	8.92	3.29	12.25	2.96	10.58
MOP (K_2O)	7.42	1.79	9.33	0.04	8.29
NPK (15:15:15)	8.42	2.79	9.33	0.04	8.75
Poultry manure	20.96	15.33	29.54	20.25	25.25
SSP (P_2O_5)	5.71	0.08	7.79	-1.50	6.48
Urea	9.92	4.29	9.42	0.13	9.67
F-LSD (P=0.05)	2.33		1.52		1.36

Moreover, four varieties of soybean TGx 1485-1D, TGx1876-4E, TGx 1904-6F and TGx 1908-8F responded better with 12.00-13.00 nodules per plant than others with approximately 10.00 nodules per plant in the first year (Table 4). This low number of nodules produced by these selected promiscuous varieties of soybean is also not in agreement with the reported performances in the savanna zones, though it is encouraging as it establishes the fact that there are native rhizobium populations capable of infecting soybean roots for nodule formation given the right conditions. In the second and combined years, some of the varieties did not obey the Leinonen (1996) prediction perfectly as TGx1904-6F with 12.03 nodules in 2008 dropped to 7.22 in 2009 and 9.39 in years combined. However, others did appreciate in the second year. TGx1908-8F also had a drop in the second year and years combined. This case may not be completely agronomic but as a result of inadvertent occurrence during computation and presentation.

Table 4: Varietal ability of six varieties of soybean to form nodules in a sub-humid environment

Treatment	2008	2009	2008 and 2009 combined
TGx 1876-4E	12.22	12.72	12.47
TGx 1903-7F	9.72	12.25	10.98
TGx 1485-1D	12.59	12.81	12.70
TGx 1844-4E	9.75	9.91	9.72
TGx 1904-6F	12.03	7.22	9.39
TGx 1908-8F	12.91	9.97	11.31
FLSD (P=0.05)	2.02	1.30	1.43

Conclusion

Based on the result of this study, achieving a vigorous growth of soybean varieties with these soil fertility management options can subsequently improve soil fertility, crop production and halt soil degradation through judicious cultivation of the legume. Moreover, agro-forestry which closely approximates the traditional shifting cultivation, known to be ecologically stable and biologically efficient and resilience for the fragile tropical soils are no longer feasible because of population growth and pressure on land needed for more food production and other non-agricultural needs. Therefore, building up a solid fertilizing scheme for soybean, not only improves its growth and yield, but also means building a solid soil fertility system for other crops like maize, because only then it will be able to fix atmospheric nitrogen enough in the soil through nodule formation. By this the rural environment can be revitalized and life made better for the resource-constrained small-holder farmers as green environment is guaranteed. Hence, this low input smallholder farmer-friendly system of managing soybean to improve its ability to form nodules in the sub-humid environment is highly recommended. The use of poultry manure and wood ash should be intensified as effective and veritable tools for influencing nodule formation in soybean varieties which will adequately deal with soil degradation, fertility loss and low crop yield, while funds usually expended on securing high input resources are conserved.

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