Influence Of Soil Incorporation Of Common Food Legume Stover On The Yield Of Maize In Sandy Soils Of Moist Savanna Woodland Of Nigeria

Egbe,O.M[1]. and Ali,A[2].
[1]Department of Plant Breeding and Seed Science,University of Agriculture,Makurdi.
[2]Department of Soil Science,University of Agriculture,Makurdi.
*Corresponding author: onyiloegbe@yahoo.co.uk Phone: +2348068698638

ABSRACT: Two separate field experiments were conducted between 2006 and 2008 to evaluate the influence of soil incorporation of common food legumes on the yield and yield related parameters of maize grown on sandy soil environment of Odoba-Otukpa in the Moist Savanna Woodland of Nigeria. Five most commonly planted traditional food legume crops[groundnut (*Arachis hypogea* var.'Camerun'), bambaranut (*Vigna subterranean* var'.Ikpeyiole'), cowpea (*Vigna unguiculata* var.'adoka white'),pigeon pea (*Cajanus cajan* var.'igbongbo') and soybean (*Glycine max* var.Samsoy 2) were incorporated as green manure after 12 weeks of field growth and also as stover after harvest into the soil in two separate experiments.NPK:15:15:15 applied at 45 kg/ha (NPK 45) and natural fallow were included as checks. The experiments were laid out in Completely Randomized Block Design. The results indicated that particle size distribution of soil in the experimental site was altered, levels of organic carbon, organic matter, total nitrogen, phosphorus and the exchangeable bases (except Na+) also increased with the addition of both the food legume and the natural fallow materials. The incorporated food legume treatments had 56-76% (when incorporated at 12 weeks of field growth) and 42.5-61.49% (when incorporated as stover) of the total grain yield of maize produced by the inorganic fertilizer treatment, but gave significantly higher grain yield of maize than the natural fallow check. Soil incorporation of food legume plant parts also produced significant effects on hundred-seed weight and nitrogen yield of maize and soil nitrogen after harvest of maize. Although NPK 45 treatment plots gave higher grain yield and other yield related parameters than the food legume treated plots, the net benefits values were higher for most of the legumes as compared to NPK 45, indicating higher profitability of food legume incorporation than the inorganic fertilizer option. [Researcher. 2010;2(8):84-90]. (ISSN: 1553-9865).

Keywords: legume stover, incorporation, NPK fertilizer, maize

INTRODUCTION:

A sandy soil will support very little plant life, unless organic matter of some kind is added to it. Organic matter contributes to plant life through its effect on the physical, chemical, and biological properties of the soil. It serves as a source of nitrogen (N) and phosphorus (P), profoundly affects the activities of microflora and microfaunal organisms, promotes good soil structure, thereby improving tilth,aeration, and retention of moisture and increasing buffering and exchange capacity of soils (Cornell University,2009).Organic matter consists of materials derived from plants(straw, leaves, aborted floral parts, dead roots) and includes such other materials as animal manures,compost,native peat, sawdust, garden refuse and sod(Williams,2009).The only way for a soil to acquire organic matter in proper proportion is for the farmer to incorporate into the soil(Williams,2009). Haque (1992) and Williams (1992) had reported increased dry matter yields of maize when legumes were incorporated into the soil before the maize was planted. Tanimu *et al.* (2007) incorporated some non-food legumes manually by hoeing into ridges spaced 75 cm apart and reported higher grain yields of maize following incorporation, but also observed that no significant differences existed between the different rates of the legume residues applied. Birch and Freyer (2007) incorporated plant biomass at depths of 15 cm and 30 cm into the soil and reported yield increases of up to 15% of wheat planted after incorporation of some non-food legumes in Kenya.

The soils of Odoba-Otukpa, where cultivation of arable crops (maize, sorghum, yam, cassava, etc.) is the major occupation of the people, have low fertility status and are physically fragile (Egbe *et al*.s, 2009).There is need to evolve suitable management technologies to preserve the soil fertility, productivity and to stabilize its structure under long term cultivation to staple foods such as maize. Incorporation of food legumes has been found to be superior to NPK fertilizer in terms of improvement of soil structure, nutrient availability and amelioration of the fragile soils (Papastylianou, 1988; Nair *et al*.1979). Thus, in addition to its economic benefits over the chemical fertilizers, farmers stand to benefit more in terms of soil fertility improvement from food legume incorporation than the fertilizers. We hypothesized that incorporation of food legume stover into the sandy soils of Odoba-Otukpa could improve the soil fertility, stabilize its structure and subsequently enhance its capacity to support profitable maize production in the region.

MATERIALS AND METHODS:

Two field experiments were conducted at Odoba-Otukpa in Ogbadibo Local Government Area (latitude 06^0 $23^/$ -07^0 $09^/$ N, longtitude 07^0 $30^/$ -07^0 $13^/$ E) of Benue State, Nigeria during 2006 to 2008 cropping seasons to evaluate the influence of soil incorporation of common food legumes on the yield and yield related parameters of maize grown in a sandy soil environment. Total precipitations during the cropping seasons were 1702.0mm ,1690.5 mm and 1645.20 mm in 2006,2007 and 2008,respectively.Twenty-four core samples collected from 0-30 cm depth at the experimental site before land preparation were bulked, air-dried and ground. Samples were sieved through 2 mm and 0.05 mm screens for determination of particle size, pH, total nitrogen (N),organic carbon (C), available phosphorus (P),the levels of potassium(K^+),calcium (Ca^{2+}), Magnesium (Mg^{2+}),Sodium(Na^+),CEC and ECEC. The various procedures used for soil analysis were as outlined by Jackson (1967).The soil of the experimental site was classified as Typic Paleustalf (USDA).

Experimernt 1: Incorporation of common food legumes as green manure plants

Five most commonly planted traditional food legume crops[groundnut(*Arachis hypogea* var.'Camerun'),bambaranut(*Vigna subterranean* var'.Ikpeyiole'),cowpea(*Vigna unguiculata* var.'adoka white'),pigeon pea(*Cajanus cajan* var.'igbongbo') and soybean(*Glycine max* var.Samsoy 2)]were sown in May of each year(2007 and 2008) on 50 m^2(5 m x 10 m) plots and laid out in a Completely Randomized Block Design(CRD) and replicated three times. These food legume crops were grown for 12 weeks and incorporated manually by hoeing into ridges 100 cm apart. The total plant population used for each of the legume plots were in accordance with the farmers' practices and these were: 110,000 plants/ha (pigeonpea); 150,000 plants/ha (cowpea); 240,000 plants/ha (soybean); 200,000 plants/ha (groundnut) and 180,000 plants/ha (bambaranut).A natural fallow plot was included as check to evaluate nitrogen dynamics in the soil. During the second week of August of each of the years of experimentation, short-duration maize (var.TZESR-W) was planted on each of the previous food legume plots at the spacing of 90 cm x 25 cm (44,000 plants/ha). Also, a 50- m^2 plot planted with the same variety of maize was included and fertilized with 45 kg N/ha as control. All other agronomic practices for maize production as recommended by BNARDA (2003) for Benue State were observed. Data on plant height, total plant biomass, seed yield, seed rows, cob weight and dry stover weight of the maize were collected from the inner 3 m x 5 m (15 m^2). Nitrogen concentration in the dry shoot of maize at harvest and soil N was estimated by indophenols colour formation method (Chaykin, 1969) after micro-Kjeldhal digestion.

Experiment 2: Incorporation of dry stover (roots, stem portions and leaves)after harvest of common food legumes.

The treatments comprised of the five common food legumes used in Experiment 1, and these were planted mid-June of both 2006 and 2007. The gross plot measured 5 m x 10 m (50m^2) for each treatment plot and laid out in Completely Randomized Block Design with three replications. The plant populations used for each food legume species were as used in Experiment 1. At the harvest of each crop, the stover and the residues from the winnowed portions of each food legume species were incorporated into the soil manually by hoeing into ridges 100 cm apart. During the last week of May in 2007 and2008, five core samples of soil from 0-30 cm depth in each of the previous legume plots were bulked, air-dried and ground for the analysis. Samples were sieved through 2 mm and 0.05 mm screens for determination of particle size, pH, total nitrogen (N),organic carbon (C), available phosphorus (P),the levels of potassium(K^+),calcium (Ca^{2+}), Magnesium (Mg^{2+}),Sodium(Na^+),CEC and ECEC. During the first week of June 2007 and 2008, maize (var.TZESR-W) was planted on each of the previous food legume plots at the spacing of 90 cm x 25 cm (44,000 plants/ha). Also, a 50- m^2 plot planted with the same variety of maize was included and fertilized with 45 kg N/ha as control. A natural fallow plot was included as check to evaluate nitrogen dynamics in the soil. All agronomic practices for the cultivation of maize as recommended by BNARDA (2003) were observed. Data on plant height, seed rows, grain yield, cob weight and dry stover weight of the maize were collected from the inner 3 m x 5 m (15 m^2). Other parameters evaluated included the nitrogen yields of the maize stover from the treatment plots as well as soil nitrogen after the maize harvest. Nitrogen concentration in the dry shoot of maize at harvest and soil N after harvest of maize was estimated by indophenols colour formation method (Chaykin, 1969) after micro-Kjeldhal digestion.

Farmer's preference rating was conducted for both experiments. This was achieved by asking two different groups consisting of 50 farmers each from the villages located around the experimental plot to score the maize produced from the incorporated food legume plots as well as those produced from the plot fertilized with 45 kg of NPK:15:15:15/ha and the fallow using the subjective weighting scale of 5 indicated below:

5= most preferred; 4=more preferred; 3=preferred; 2=not preferred and 1=rejected. The scores were collated for each of the treatments and recorded in percentages.

Farmers are mostly concerned with the profitability of their farm enterprises. Njoroge *et al*. (1993) estimated the net benefit of intercropping coffee with food crops by subtracting the total variable costs from the gross profits. Similarly, Egbe (2005) had estimated the total profit and the marginal benefit: cost ratio from investment on different farm inputs used in pigeonpea/sorgum intercropping system. Marginal return values were therefore computed for each of the treatment plots in both experiments, thus:

Marginal returns=gross profits-total variable costs.

Data collected for the two years were pooled and analyzed using GENSTAT Release 11.1 (2009), following standard analysis of variance procedures (Gomez and Gomez, 1984) and least significant difference (LSD) test at 5% probability level was used to compare the treatment means.

RESULTS:

The physico-chemical properties of the soil in the experimental site was affected by incorporation of stover of all the food legume crops tested and the natural fallow for two years when compared to the soil at the beginning of the experiment in 2006(Table 1).The particle size distribution was altered(sand component decreased, while silt and clay increased) after the incorporation of the various food legume crop stover and the natural fallow plants, particularly after the incorporation of the pigeonpea, cowpea and the soybean stover. The textural class of the soil in the experimental site was also altered from sand to sandy loam by the incorporation of the food legume and fallow plant materials. Similarly, acidity decreased with the incorporation of the various food legumes and the natural fallow materials. The levels of organic carbon, organic matter, total nitrogen (N),phophrus(P) and the exchangeable bases(except Na+) also increased with the addition of both the food legume and the natural fallow materials. Exchangeable Ca dominated the exchange complex in most of the soils where food legume had been incorporated. The levels of N and P were particularly increased with the addition of pigeonpea plant stover into the soil (Table 1).

Table 1: Physical and chemical properties of surface soil (0-40 cm) before after experimental treatments.

Soil parameter	Before planting	*After incorporation of legume stover					
		Bambaranut	Cowpea	Groundnut	Pigeonpea	Soybean	Fallow
Sand (%)	92.45	88.4	81.89	86.4	80.40	82.47	89.12
Silt (%)	4.41	9.20	15.20	11.34	15.2	13.34	9.21
Clay (%)	3.14	2.40	2.91	2.26	4.4	4.19	1.67
Textural class	Sand	Loamy sand	Loamy sand	Loamy sand	Loamy sand	Loamy sand	Loamy sand
pH (H_2O)	5.78	6.20	6.40	6.30	6.50	6.40	5.90
%Organic Carbon	0.48	0.68	0.85	0.62	1.14	0.75	0.57
Org. matter(%)	0.83	1.17	1.48	1.07	1.96	1.29	0.98
Total N(%)	0.045	0.12	0.19	0.13	0.21	0.16	0.14
Available P(cmol kg^{-1})	2.3	4.2	4.80	4.2	5.8	4.6	3.60
Ca2+(cmol kg-1 soil)	0.71	0.81	0.99	0.76	0.99	0.89	0.85
Mg2+(cmol kg-1 soil)	0.22	0.24	0.25	0.19	0.28	0.23	0.25
K2+(cmol kg-1 soil)	0.27	0.44	0.37	0.41	0.53	0.44	0.35
Na+(cmol kg-1 soil)	0.20	0.21	0.22	0.19	0.15	0.23	0.20
Exch.	0.31	0.51	0.59	0.48	0.64	0.59	0.34

acdity(cmol kg-1 soil)							
ECEC(cmol kg-1 soil)	1.41	2.00	2.12	1.93	2.37	2.18	1.59

*: analysis done just before planting maize in 2008 cropping season.

NPK 45 (NPK: 15:15:15 applied at 45 kg/ha) produced significantly higher plant height (1.77 m), dry cob weight (2.55 t/ha), number of seed rows (15.17), grain yield (1.65 t/ha) and dry stover weight (2.27) of maize than the plots in which food legumes were incorporated, which in turn gave significantly higher levels of these same yield parameters than the fallow (Table 2). However, cowpea, soybean and pigeonpea gave similar results of plant height, grain yield and dry stover yield of maize, which were significantly higher than those produced by the other food legume crops tested .Maize grown on the fallow plot obtained lowest plant height (0.64 m), number of seed rows (4.00), grain yield (0.22 t/ha) and dry stover yield (0.43 t/ha) of maize. All plots had more than one cob per plant, except the groundnut treatment. NPK 45, pigeonpea and cowpea treatment plots had significantly higher farmer's preference ratings (22.33 %, 21.67% and 18.33%, respectively) than the other treatment plots (Table 2).The fallow plot gave the least value (2.67%) of the farmer's preference rating. Net benefit values varied from ₦1, 710.00/ha (fallow) to ₦22, 310.00/ha (pigeonpea) with a mean of ₦17, 110.00/ha.Pigeonpea, soybean, cowpea and bambaranut produced comparable net benefits and these were significantly higher than values for NPK 45,groundnut and the fallow check (Table 2).

Table 2: Effect of soil incorporation of food legume shoots on selected maize yield parameters, farmer's preference rating and marginal returns.

Food legume species	Plant Hgt (m)	No. of cobs	Dry cob weight (t/ha)	No. of seed rows	Grain yield (t/ha)	Dry stover weight (t/ha)	Farmer's preference rating(%)	Net benefits (₦'000/ha)
Bambaranut	1.08	1.03	1.41	8.25	0.92	1.59	11.67	19.59
Cowpea	1.69	1.07	2.05	11.42	1.35	1.98	18.33	20.74
Groundnut	1.27	0.85	1.80	10.00	1.03	1.36	13.00	16.67
Pigeonpea	1.57	1.02	1.91	11.75	1.15	1.76	21.67	22.31
Soybean	1.64	1.12	1.99	10.00	1.27	1.92	11.33	21.07
Fallow	0.64	1.05	0.43	4.00	0.22	0.68	2.67	1.71
NPK 45	1.77	1.15	2.55	15.17	1.65	2.27	22.33	17.71
Mean	1.38	1.04	1.74	10.08	1.08	1.66	14.29	17.11
LSD(0.05)	0.17	0.19	0.12	0.96	0.13	0.21	4.72	3.47

Plant Hgt: plant height of maize
No. of cobs: number of cobs/plant of maize
No. of seed rows: number of seed rows/cob of maize
NPK 45: NPK: 15:15:15 fertilizer applied at 45 kg/ha.

NPK 45 treatment plot gave the highest plant height(1.70 m), dry cob weight(2.37 t/ha), number of seed rows(14.67) and grain yield(1.74 t/ha) when compared to the other treatment plots (Table 3).Maize planted in plots incorporated with cowpea, pigeonpea and soybean stover had very comparable plant height, dry cob weight and grain yield, which were significantly more than those produced by bambaranut, groundnut and the fallow .The fallow plot(check) produced the lowest plant height, dry cob weight and grain yield of the succeeding maize. Similarly, only the fallow treatment plot had significantly lower number of cobs than the other treatment plots (Table3). Farmer's preference ratings of NPK 45 and pigeonpea treatment plots were significantly superior to the other treatments in the experiment. Farmer's preference rating of maize planted in the plot incorporated with cowpea stover (16.67%) was significantly higher than plots incorporated with bambaranut(10.67%), groundnut(11.00%) and soybean(9.33%), which in turn were superior to the fallow(2.00%)(Table 3). Maize planted on plots in which pigeonpea and cowpea stover had been incorporated gave the highest significant marginal return values (₦22, 000.00/ha and ₦18, 590.00/ha, respectively), while the fallow plot produced a negative value (-₦2, 710.00/ha) (Table 3).

Table 3: Effect of soil incorporation of food legume stover on selected maize yield parameters, farmer's preference rating, and marginal returns.

Food legume species	Plant Hgt (m)	No. of cobs	Dry cob weight (t/ha)	No. of seed rows	Grain yield (t/ha)	Farmer's preference rating(%)	Marginal returns (₦'000/ha)
Bambaranut	1.19	1.27	1.22	8.17	0.82	10.67	13.50
Cowpea	1.35	1.17	1.46	10.67	0.99	16.67	18.59
Groundnut	1.12	1.1	1.00	8.00	0.74	11.00	12.67
Pigeonpea	1.32	1.14	1.54	11.33	1.07	23.33	22.00
Soybean	1.24	1.13	1.38	9.67	0.93	9.33	13.70
Fallow	0.42	0.33	0.07	0.17	0.01	2.00	-2.71
NPK 45	1.70	1.13	2.37	14.67	1.74	25.33	13.66
Mean	1.18	1.03	1.29	8.79	0.89	14.29	13.19
LSD(0.05)	0.19	0.67	0.36	1.97	0.23	2.92	2.66

Plant Hgt :plant height of maize
No. of cobs: number of cobs/plant of maize
No. of seed rows: number of seed rows/cob of maize
NPK 45: NPK: 15:15:15 fertilizer applied at 45 kg/ha.

Soil incorporation of food legume plant parts both at 12 weeks of growth and after harvest as stover produced significant effects on hundred-seed weight (100-sw) and nitrogen yield (Ny) of maize and soil nitrogen(soil N) after harvest of maize (Table 4). In both cases of incorporation, NPK 45 treatment plots gave the highest 100-sw.Maize planted after incorporation of fresh the food legume plant parts and after harvest as stover produced similar results of 100-sw and these were significantly higher than that produced by the natural fallow treatment plot. N yield of maize seeds from plots planted after incorporation of pigeonpea stover(1.76%) was significantly higher than those from groundnut(1.64%) , NPK 45(1.61%) and bambaranut(1.53%) ,which in turn were significantly higher than that obtained from the fallow(1.41%) (Table 4). Cowpea and soybean treatment plots gave similar results of N yield (1.71%, 1.68%, respectively) to pigeonpea plots. The results of N yield of maize seeds from plots incorporated with fresh food legume plant parts were however different, as all legume treatment plots produced similar results to NPK 45,but these were superior to Ny of maize seeds from the natural fallow plots. Soil N results indicated higher levels in NPK 45 plots than the food legume treated plots, which in turn were higher than the fallow when incorporation was done with fresh legume plant parts (Table 4). The situation was however different when soil incorporation was done using the food legume stover; soil N from NPK 45, pigeonpea, cowpea had comparable results and these were more than the values obtained from the soybean and bambaranut plots, which produced significantly higher soil N than the groundnut and the fallow treatment plots (Table 4).

Table 4: Effect of soil incorporation of fresh food legume plant parts stover on the 100-seed weight (g), nitrogen yield(%) of maize seed and soil nitrogen (g/100g) after harvest of maize.

Food legume	Grown for 12 weeks			Legume stover		
	100-sw	Ny	Soil N	100-sw	Ny	Soil N
Bambaranut	27.59	1.41	0.15	26.41	1.53	0.10
Cowpea	29.09	1.58	0.18	28.67	1.71	0.13
Groundnut	26.44	1.47	0.14	26.92	1.64	0.08
Pigeonpea	28.92	1.63	0.19	29.07	1.76	0.13
Soybean	27.49	1.58	0.14	28.15	1.68	0.11
NPK45	30.15	1.64	0.21	30.62	1.61	0.14
Fallow	20.72	0.41	0.09	24.84	1.41	0.07
Mean	27.24	1.39	0.16	27.61	1.62	0.11
LSD(0.05)	2.88	0.75	0.03	1.46	0.10	0.02

100-sw:100-seed weight of maize.
Ny:nitrogen yield of maize seed

DISCUSSION:

The alteration of the physico-chemical properties of the soil at the experimental site at Odoba-Otukpa after the incorporation of the food legume stover might have resulted from the decomposition of these food legume stover thereby increasing organic matter content of the soil which might subsequently have improved the soil structure. It is common knowledge that addition of easily decomposable organic residues leads to the synthesis of complex organic compounds that bind soil particles into structural units called aggregates. The increased organic matter content of the soil might also have resulted in the enhanced CEC and the increased level of total N and available P in the soil. Organic matter improves the texture of sandy soil by filling the spaces between the tiny stones (of which sand is actually composed).The filling of the spaces also increases the water- holding and nutrient-holding capacities of the soil. Tanimu *et al.*(2007) had reported that organic matter enhanced soil CEC, improving soil aggregation; and subsequently, water retention and biological activity. Although the NPK 45 treatment produced significantly taller plants, higher grain yields, dry cob weight and dry stover yields of maize than all the incorporated legume treatments (either as fresh shoot or as stover), it must be noted that the incorporated legume treatment plots had 56-76%(when incorporatedfresh) and 42.5-61.49%(when incorporated as stover) of the total grain yield produced by the inorganic fertilizer treatment. This implies that nearly 30% of the potential yield of maize in this region could be realized with incorporation of food legume stover, especially that of pigeonpea ,since inorganic fertilizer recommendation rate for optimal production of maize in this region is put at 90 kg N +45 kg P_2O_5 +45 kg K_2O /ha(BNARDA,2003). Haque(1992) and Williams(1992) had reported increased dry matter yields of corn when legumes were incorporated into the soil .Also, in the work on soil fertility improvement with velvetbean (*Mucna spp*.) for integrated management of purple witchweed (*Striga hermonthica*) in maize in Benue State,Nigeria, Shave (2008) had observed yield increases of maize crop when mucuna was incorporated as green manure. Similarly, Birech and Freyer(2007) had reported increased yield of wheat when Tithonia was incorporated as green manure in Kenya. These workers ascribed the significant effect of legume incorporation on the yield of maize to their potential of supplying plant nutrients, particularly N. There were yield differences (including 100-sw, Ny and soil N) of maize among the different food legume treatments .These differences were likely related to the quantity and quality of the materials incorporated. Tanimu *et al.* (2007) had indicated that a predictable consequence of the variable N concentration in different legume residue is that they will contribute varying amounts of N to the soil and likewise to the following crop. The biological yields of the maize from plots incorporated with food legumes, either as fresh shoot or as stover, were also superior to the yield of maize from the natural fallow checks. This result was probably so because, the natural fallow plots were grass-dominated, having less favorable C: N ratio when compared to the food legumes. Giller and Wilson(1991) indicated in their reports that, legume residues commonly have C:N ratios less than 30:1 and therefore tend to release N and decompose rapidly. It must also be noted that, although NPK 45 treatment plots gave higher grain yield and other yield related parameters than the food legume treatment plots, the net benefit values were higher for most of the legumes as compared to the NPK 45.This might be due to the higher cost of the inorganic fertilizer material and the cost of its application as compared to the food legume materials and the cost of incorporation. The farmer’s preference rating of the various technological options indicated that they preferred the use of inorganic fertilizer to several of the legume treatments probably because of its ease of application and the high concomitant yields, but it must be observed that this preference rating was not significantly different from that obtained by the soil-incorporated pigeonpea option.

CONCLUSION:

Incorporating common food legume stover into the sandy soils of the Moist Savanna region of Nigeria resulted in less grain yield of maize and other yield related parameters than obtained with inorganic fertilizer, but net benefit values indicated higher profitability of food legume incorporation than the inorganic fertilizer option .It however led to the improvement of soil structure, stability and texture and is capable of sustaining maize production over time compared to the other treatments.

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