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Influence of legume fallow on soil properties and yield of maize in South Western Nigeria

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Abstract

The study was conducted to investigate the influence of some legume fallows on the physico-chemical properties of soil and grain yield of maize in Southwestern Nigeria. Treatments consisting of four fallows with *Mucuna utilis*, *Centrosema brasiliensis*, *Canavalia ensiformis* and *Cajanus cajan* were planted and allowed to fallow for three years. The fallow crops were incorporated into the soil at the end of each of the three years. Maize was planted as indicator crop only at the end of the third year. Soil and plant analyses were done. Maize was harvested at maturity and grain yield calculated at 12% moisture content.

Results showed that the fallow crops with exception of centrosema improved soil fertility and increased soil organic matter from 1.07% at pre-crop to 2.10, 1.90% and 1.86%, respectively on the cajanus, canavalia and mucuna plots after three years of fallow. The cation exchange capacity and phosphorus however, increased almost three fold in these fallow plots. The fallow crops positively affected nutrient concentration in leaf tissue and grain yield of maize. The coefficient of correlation (r) for N, P and K with yield was 0.93, 0.77 and 0.30 respectively. In term of effectiveness the fallow crops are rated in the following ascending order - cajanus, mucuna, canavalia, centrosema and bush. Application of NPK fertilizer (50 kg N/ha) on the plots under fallow with natural bush and centrosema gave respectively 67 and 79% yield increase compared with plots without fertilizer. There was indication that, little or no fertilizer would be required on the other treatment plots depending on targeted yield and soil test.

1 Introduction

Any cropland kept under continuous cultivation without appropriate soil management loses its strength in supporting good and sustainable crop yield. This is due to deterioration in soil physical, chemical and biological properties (Juo and Lal, 1977). To worsen the soil conditions, farmers' practices, which involve intensive cropping cause rapid decline in soil fertility (Jones, 1971, Abdulahi and Lombin, 1978). The traditional system commonly acceptable to most farmers in restoring soil fertility of

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cropland is by allowing it to rest (fallow) for a long period of time. Restoration of soil fertility under this system takes over 10 years of fallow (AGBOOLA and UNAMMA, 1994). However, long-term fallow could not be sustained in recent times due to increased population pressure on land. Also, land tenure system commonly adopted in many farming communities hinders direct ownership of land put under fallow. Restoration of soil fertility by fallowing for a long period is therefore not well suited for the present day food requirements.

Shortening of fallow period, therefore becomes attractive to farmers that are actively engaged in food production. However, the use of shortened fallow without appropriate measure of enhancing soil fertility gradually impoverishes the soil and causes poor crop yield. Short-term natural fallow has no measurable effect in regenerating soils exhausted by cropping (PIERI, 1992). Such fallow is not long enough to replace the nutrients removed by crops. Therefore planting of fallow with appropriate legume species can improve soil fertility through nitrogen fixation, recycling of nutrient, which consequently increases the level of organic matter in the soil.

Proper management of selected fallow species can also suppress weeds, reduce erosion and sustain soil fertility. Despite some work earlier carried out by various researchers on maximization of the potential of legumes for soil fertility enhancement, it is advantageous to further investigate the effectiveness of the crop species under different soil and agroecological environments and also some other benefits derivable from using such legumes as fallow crops. The numerous work involving some legume crop plants in intercropping, green manuring, alley cropping, cover cropping and rotational cropping were reported by some scientists
(KANG *et al.*, 1990, OKIGBO and LAL, 1977, OKIGBO and GREENLAND, 1976 and SINGH, 1974).

This paper further examines the effect of legumes planted as fallow crops on soil properties and maize yield in the humid forest zone of South western Nigeria.

2 Materials and Methods

The experiment was conducted at Institute of Agricultural Research and Training cropping research station at Moor Plantation at Ibadan in the humid forest zone of South western Nigeria. The site used for the experiment had earlier been put to continuous cultivation for eight years and recently cropped for four consecutive years with maize and maize/cassava crop mixture before the trial was initiated. The soil of the experimental site was Iwo series classified as alfisol (Rhodic plinthustalf - USDA). The soil was ploughed and harrowed once. Pre-crop soil samples were taken and analysed in the laboratory.

The fallow crops planted were *Mucuna utilis, Centrosema brasiliensis, Canavalia ensiformis and Cajanus cajan*. For the first three crops spacing was 1.00m x 0.50m and for Centrosema, it was 0.75m x 0.50m. The fallow crops were planted at the on-set of early rains. Plots with natural bush served as check for the fallow crops. The major plot size was 14m x 5m and the treatments were arranged in strip design and replicated three times. With the exception of bush fallow, one manual weeding was carried out on plots with fallow crops before fallow establishment. Although there was incidence of fire outbreak at the end of first year fallow, the crops were replanted and left to fallow further in subsequent years. In the third year however, centrosema was replanted and rogueing of weed was carefully carried out on the canavalia and mucuna plots to enhance re-establishment of the fallows.

At the end of the first and second year, a subplot of 3m x 5m was earmarked from the major plot. Plant biomass was worked into the soil and soil samples were taken for some physico-chemical properties analysis in the laboratory (IITA, 1979). After three years of fallow, plants biomass was again worked into the soil on the remaining treatment plot (8m x 5m). Soil samples were taken before cropping and analyzed in the laboratory. Microbial population was estimated on the Huchinson,s agar for bacteria and actinomycetes as modified by BHAT and SHATTY (1949), and on potatoe dextrose agar for fungi (BARNETT, H. L.1960). The plot was divided into two sub-plots. The first consisted of fallow treatment alone and on the second sub-plot application of NPK 20-10-10 at 50 kg N/ha was done 2 weeks after planting of maize. The variety of maize planted was DMRLSR-Y. Three seeds were sown per hole and later thinned to one plant per stand. The planting space was 75cm x 25cm. Herbicide was applied immediately after planting and was followed by one light weeding few weeks before tasseling of maize. Other cultural operations were carried out as recommended in the IAR&T package of recommendations for South western zone of Nigeria (IAR&T, 1991).

Maize ear leaf was sampled and analyzed for nutrient content at 4 and 8 weeks after planting. The leaf samples were digested with 2:1 mixture of HNO_3 and $HClO_4$ and nitrogen was determined on the tecnicon II Autoanalyzer. Ashing of some subsamples took place in the muffle furnace at 450° C and K, Ca, Mg, Zn were determined on the Atomic Absorption Spectrophotometer. Phosphorus was determined spectrophotometrically using Ammonium Molybdenum Ascorbic Acid method. Maize was harvested at maturity and the grain yield was computed at 12% moisture content.

3 Results

3.1 Soil Properties

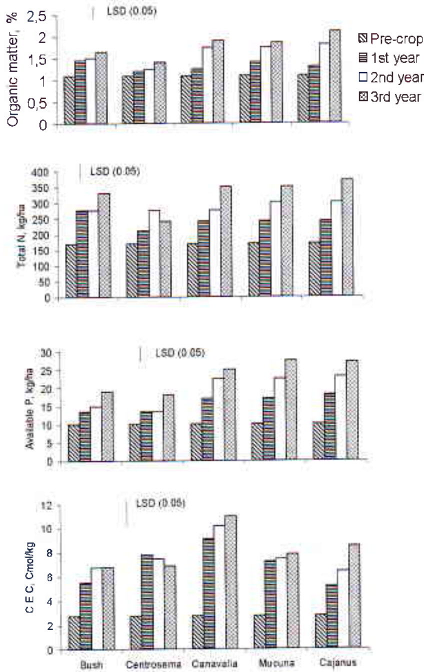
Table 1 shows some physical and chemical properties of the soil at pre-crop, after one two and three years of fallow. The first year fallow showed no marked changes in soil texture, pH and organic C over the pre-crop soil analysis results. However, the C E C increased between two and four folds (Table 1). This could probably be due to burning incidence that occurred on the trial site, which might have raised the ash level in the soil. On the other hand, the available phosphorus increased by 30 - 67%. At the end of the second and third year, the soil texture remained loamy sand with some improvement in pH and organic carbon. In the second year, mucuna and cajanus increased the soil nitrogen status respectively by 47 and 76% and the phosphorus level by 126 and 130% respectively when compared with what was obtained at pre-crop soil sampling period.

Table 1: Some physical and chemical properties of the soil under the legume fallows

Treatment	Sand %	Silt %	Clay %	pH	org C %	Ca	Mg	K	CEC	N g/kg	P mg/kg
						←	Cmol/kg	→			
Pre-crop	89	6	5	5.7	0.62	1.40	0.90	0.20	2.76	0.68	3.40
1 year fallow											
Bush	87	7	6	6.0	0.85	2.96	2.01	0.14	5.60	0.90	3.63
Mucuna	87	7	6	5.8	0.72	4.20	2.80	0.13	7.32	0.80	5.42
Centrosema	88	6	6	5.5	0.85	4.30	2.66	0.17	7.80	0.70	4.42
Cajanus	87	6	7	5.9	0.75	2.90	1.93	0.17	5.25	0.80	5.68
Canavalia	87	7	6	5.9	0.72	6. 37	4. 22	0.21	11.17	0.80	5.46
LSD at 5%	6.2	2.5	2.2	0.27	0.13	2.95	1.98	0.06	4.08	0.14	1.75
CV, %	10.5	9.3	11.1	11.6	17.5	19.8	12.5	14.2	21.5	16.2	15.5
2 years fallow											
Bush	86	7	7	6.2	0.88	3.65	2.58	0.18	6.62	0.90	4.88
Mucuna	85	8	7	6.0	0.97	4.50	2.75	0.15	7.66	1.00	7.68
Centrosema	86	8	6	5. 6	0.72	4.42	2.62	0.18	7.48	0.90	4.42
Cajanus	84	10	6	6.2	1.06	4.15	2.04	0.18	6.74	1.20	7.84
Canavalia	85	8	7	6.2	0.98	6.05	3.61	0.26	10.24	0.90	7.45
LSD at 5%	5.4	2.5	1.8	0.11	0.90	1.02	1.24	0.09	2.27	0.44	1.26
CV, %	12.5	10.2	8.7	13.4	15.5	17.6	13.8	16.4	16.2	12.5	17.3
3 years fallow											
Bush	85	8	7	6.2	0.94	3.85	2.54	0.20	6.78	1.10	6.40
Mucuna	85	9	6	6.1	1.08	4.80	2.75	0.20	8.04	1.20	9.20
Centrosema	85	7	8	5.9	0.79	4.02	2.60	0.19	6.82	0.80	5.88
Cajanus	84	10	6	6.3	1.21	4.92	2.10	0.20	8.43	1.30	8.94
Canavalia	84	9	7	6.4	1.10	6.43	3.84	0.28	10.82	1.20	8.45
LSD at 5%	6. 8	3.4	2.6	0.05	0.10	1.38	1.45	0.09	2.05	0.08	1.67
CV, %	10.2	11.3	9.5	12.6	11.5	12.3	16.2	14.1	15.8	12.5	14.2

However, after three years of fallow there were marked changes in some soil properties. The mucuna, natural bush, cajanus and canavalia raised the soil pH by 0.4, 0.5, 0.6 and 0.7 units, respectively. For nitrogen, the increase was between 62 and 91% and for phosphorus it was between 88 and 170%. The soil organic matter content increased with period of fallow (Figure 1). The cajanus and canavalia gave slightly higher effect on soil organic matter than other fallow crops. They also increased the organic matter content by 95 and 77%, respectively when compared with the values at pre-crop period. Likewise, they added to the soil 360 - 390 kg N/ha and 25 - 28 kg P_2O_5/ha after three years of fallow.

Figure 1: Effect of leguminous fallow crops on soil properties at different fallow periods



3.2 Ear Leaf Tissue Nutrient Concentration

Table 2 shows the concentration of some plant nutrients in maize leaf tissue at 4 and 8 weeks after planting sampled from the unfertilized plots. Nutrient concentration was highest in plants grown after mucuna and cajanus fallow. The effect of natural bush and centrosema fallow was lower than that of other legume fallow. Cajanus, mucuna and canavalia highly improved the concentration of phosphorus and magnesium in the plant. On the whole, nitrogen in the leaf tissue was strongly correlated with maize yield ($r = 0.93$). Whereas, the coefficient of correlation between phosphorus and yield was medium ($r = 0.77$), while that between potassium and yield was low ($r = 0.30$).

3.3 Maize Yield

The effect of the various fallow crops on maize yield is shown in Figure 2. Cajanus, mucuna and canavalia were highly promising. The least effect was obtained from bush followed by centrosema. Application of 50kg N/ha NPK 20-10-10 on the second fallowed subplots occupied by natural bush and centrosema gave significant ($p = 0.05$)

increase in maize yield. The yield increased by 67 and 69% respectively over the yields on the fallowed plots without fertilizer. However, there were 14%, 12% and 9% yield increases from canavalia, mucuna and cajanus, respectively when fertilizer was applied. This indicates that additional use of fertilizer on soil fallowed with the later three crops might not be really necessary. Whereas, additional fertilizer input was required after putting the land to fallow for three years with natural bush re-growth. This will attract extra cost on production and therefore reduces farmer's profit.

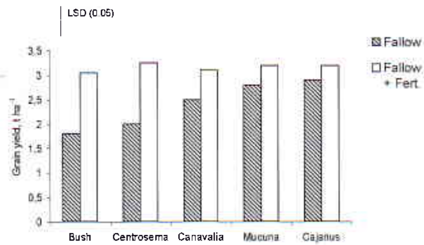
Table 2: Effect of fallow crops on the nutrient concentration in maize leaf tissue.

Treatment	N, %		P, %		K, %		Ca, %		Mg, %		Zn, %	
WAP *	4	8	4	8	4	8	4	8	4	8	4	8
Bush	2.04a	1.65c	0.28b	0.22b	3.55b	2.54a	0.21a	0.16b	0.05b	0.12a	40b	60b
Centrosema	2.10a	1.68c	0.25b	0.27b	2.85b	2.04b	0.22a	0.15b	0.06b	0.09b	55a	50b
Canavalia	2.25a	1.85b	0.33a	0.29b	3.25b	2.72a	0.28a	0.21a	0.10b	0.13a	67a	88a
Mucuna	2.38a	1.84b	0.32a	0.34b	3.20b	2.58a	0.27a	0.22a	0.09b	0.13a	65a	92a
Cajanus	2.30a	2.04a	0.30a	0.51a	3.68a	2.32b	0.30a	0.20a	0.14a	0.12a	58a	90a

* WAP - weeks after planting

Figures having the same letters in the column are not significantly different at $p = 0.05$.

Figure 2: Effect of some leguminous fallow crops on maize yield.



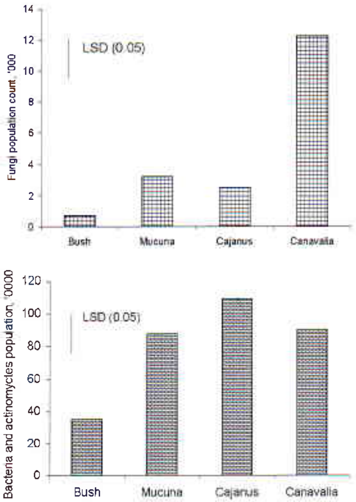
3.4 Nutritional Values

In some parts of Nigeria, the seeds of cajanus are edible and serve as protein supplement in human and livestock nutrition. However, the nutritional value of mucuna seeds has not been fully investigated. Mucuna seeds contain high value of oil and protein, which would make the crop to be useful in human and animal nutrition and would probably be of medicinal values. From our own investigation mucuna contains about 21% protein, 3.8% crude fibre, 4.2% total ash, 2.6% potassium and less than 1% of other important elements. Canavalia on the other hand, contains about 11.3% protein, 9.6% crude fibre, 4% total ash. Further investigations on the nutritional values of the two crops would be required.

3.5 Microbial Population

Effect of some of the fallow crops on the population of soil microbes is presented in figure 3. The least fungi, bacteria and actinomycetes population counts were observed in soils from the bush fallow plot. Fungi population due to canavalia was twice of that from mucuna and cajanus when added together. Cajanus cajan gave the highest population of bacteria and actinomycetes (108×10^5) and was followed by that from canavalia (90.5×10^5).

Figure 3: Effect of fallow crops on microbial population in the soil.



4 Discussions

The natural bush fallow comprised of heterogenous plant population predominantly occupied by *Pannicum maximum*. Although, *Centrosema brasiliensis* is a leguminous crop, it produced the least biomass (2.31 - 2.98 kg/m^2) and could not regenerate well in the following season. Cajanus fallow was most convenient to handle as a fallow crop. It could even regenerate if it was cut back in the following growing season. It provided a dense and wide canopy and produced high amount of biomass (4.5-6.8 kg/m^2). It completely formed 70% groundcover in the first year and about 95% groundcover in the second year while, the canopy and leaf falls (serving as mulch) smothered the weeds effectively at the end of the second year. The crop suppressed weed biomass and reduced it to about 40% and 15% when compared with centrosema and canavalia, respectively.

The canavalia also has almost similar characteristics as for the cajanus. However, it was more difficult to manage than cajanus when put to fallow. The crop is not as popular with farmers as cajanus and the seeds have not yet been introduced to Nigerian farming communities. Mucuna, like cajanus, was highly effective in improving soil fertility and increasing crop yield. It produced high amount of biomass (4.8 - 5.6 kg/m^2). It is an annual crop but would regenerate in subsequent years and would be adapted as fallow crop if well managed. However, it created a great difficulty in managing it for three years. Mucuna was able to form an effective groundcover as from 10 weeks after planting. It effectively suppressed weeds even better than cajanus and canavalia in the first year fallow period.

The general attributes of the fallow crops as discussed above contributed principally to their effectiveness when used as source of soil fertility enhancement. Cajanus was able to add more organic matter to the soil than other fallow crops whereas, mucuna improved the CEC of the soil better than the rest fallow crops.

5 Conclusions

Planting of improved fallow crops enhanced soil properties and yield of maize. In term of effectiveness, the fallow crops could be arranged in the ascending order - cajanus, mucuna, canavalia, centrosema and bush. Cajanus fallow was easier to maintain and could be left fallow for three or more years. In order to obtain optimum crop yield, cropping of land left fallow for three years with natural bush and centrosema required more fertilizer input than when cajanus, mucuna and canavalia were planted.

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