Effect of mucuna intercropped with maize on soil fertility and yield of maize

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ABSTRACT

Two field trials were used to evaluate the effect of mucuna (*Mucuna utilis*) intercropped with maize (*Zea mays* L.) on soil fertility and maize yield. In Experiment I, mucuna seeds were sown at 0, 2, 4, 6 and 8 weeks after planting (WAP) of maize. A basal application of 50 kg N/ha was administered. These treatments were compared with control (no fertilizer, no mucuna), sole application of 50 and 100 kg N/ha. In Experiment II, complementary application of 0, 50 and 100 kg N/ha with incorporation of mucuna biomass, which was sown in the previous year, were administered to maize. The results showed that intercropping of maize with mucuna at planting (0 WAP) recorded averagely 46, 60 and 87 per cent of the yields for maize that received 100, 50 and 0 kg N/ha alone, respectively. The maize yield increased as sowing date of mucuna was delayed. Undersowing of mucuna at 6 and 8 WAP with application of 50 kg N/ha resulted in 30 - 62 per cent higher yield than at 0 - 4 WAP, and was comparable (91%) with application of 100 kg N/ha. It also had residual effect of average yield increase of 52 per cent over the latter. Soil analysis showed positive residual effect on soil fertility. Planting of mucuna under maize raised the organic C, exchangeable Ca and Mg by 81, 14 and 28 per cent, respectively, when compared with the chemically fertilized soil. The soil N and P levels also showed 48 and 25 per cent increase, respectively. Complementary application of 50 kg N/ha with incorporation of mucuna biomass increased plant height, biomass weight, and grain yield of maize by 18, 23 and 31 per cent, respectively, compared with incorporation of mucuna alone. The former was equally effective as the complementary use of 100 kg N/ha. The results suggest that undersowing of mucuna in relay with maize could be a good practice for sustaining soil fertility in a cereal-based cropping system.

RÉSUMÉ

ADEDIRAN, J. A., OKANDE, M. O. & OLUWATOYINBO, F. I.: *Effet de mucuna semé entre les lignes de maïs, sur la fertilité de sol et le rendement de maïs.* Deux essais sur le terrain se déroulaient pour évaluer l' effet de mucuna *(Mucuna utilis)* semé entre les lignes de maïs *(Zea maïs* L.) sur la fertilité de sol et le rendement de maïs. En expérience 1, les graines de mucuna étaient semées à 0, 2, 4, 6, et 8 semaines après la plantation (0 SAP) de maïs. Application basale de 50 kg N/ha était faite. Ces traitements étaient comparés avec le contrôle (sans engrais; sans mucuna), application seule de 50 et 100 kg N/ha. En expérience II application complémentaire de 0, 50 et 100 kg N/ha avec l'incorporation de biomasse de mucuna, semé l'année précédente, était faite au maïs. Les résultats montraient que semailles de maïs entre les lignes de mucuna à la plantation (0 SAP) donnait en moyenne 46, 60 et 87 pour cent de rendements obtenus de maïs qui recevait respectivement seule 100, 50 et 0 kg N/ha. Le rendement de maïs augmentait comme la date de semaille de mucuna était retardée. Les semailles insuffisantes de mucuna à 6 et 8 SAP avec l'application de 50 kg N/ha résultait en 30 - 62 pour cent de rendement plus élevé qu'à 0 - 4 SAP et était bien comparable (91 %) avec application de 100 kg N/ha. Il donnait également l'effet rénsiduaire d'une augmentation de rendement moyen de 52 pour cent au-dessus de la dernière. L'analyse de sol montrait un effet résiduaire positif sur la fertilité de sol. Plantation de mucuna sous le maïs élevait le C organique, Ca et Mg échangeable respectivement par 81, 14 et 28 pour cent lorsque comparé avec les sols d'engrais chimique. Les niveaux d'azote et de phosphore du sol montraient également une augmentation respective de 48 et 25 pour cent. Application complémentaire de 50 kg N/ha avec l'incorporation de biomasse de mucuna augmentait taille de plante, poids de biomasse et rendement de graine de maïs respectivement par 18, 23 et 31 pour cent comparé avec l'incorporation de mucuna seul. La première était également efficace comme l'utilisation complémentaire

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de 100 kg N/ha. Dans l'ensemble, ces résultats suggère que les semailles insuffisantes de mucuna entre les lignes de maïs pourrait être une bonne pratique pour soutenir la fertilité du sol dans le système de culture basé sur la céréale.

Introduction

Enhancement of crop production through practices which improve soil fertility is one of the major ways of increasing food production in the West African sub-region where the population progressively increases. Due to the low-income status of most farmers in the sub-region, the use of high external technical input to maintain soil fertility is rarely affordable and, therefore, unreliable. With the introduction of newly developed high - yielding varieties and modern methods in crop production, the inherent low soil fertility and low availability of chemical fertilizers constitute a major constraint to food production. The research work by Tian & Kang (1998) and Tian *et al.* (1999) focused increased attention on integrated soil fertility management practices involving the use of biological nutrient sources for improving the soil of the tropics. Their work supports the findings of earlier work by Kang & Attah-krah (1990).

The use of leguminous cover crops has been considered as a good source of improving soil fertility because of their ability to fix atmospheric nitrogen. The crops can form groundcover rapidly and also produce sufficient biomass that is easily decomposed in the soil (Carsky *et al.,* 1998). Also, they serve as live-mulch and protect the soil from heat of the sun and impact of rainfall, reduce soil surface run-off and erosion, and improve the soil structure and water infiltration capacity (Vine, 1953; Okigbo & Lal, 1977; Akobundu, 1980; Wilson, Lal & Okigbo, 1982).

The importance of mucuna in crop production has been tested extensively in Nigeria (Vine, 1953). The cover crop was found to maintain soil productivity and crop yields for 25 years in a rotation experiment on an IITA experimental farm in southwestern Nigeria. In another studies, mucuna at full establishment produced high biomass which suppressed weeds (Fujii, Shibuya & Yasuda, 1992) and improved soil fertility (Le Mare, Pereira & Goedert, 1987; Van Noordwijk *et al.,* 1995; Yamoah *et al.,* 1996). Also, Lathwell (1990), Burle *et al.* (1992), and Becker & Johnson (1998) put the fertilizer placement values of mucuna to be substantial, and soil improvement after mucuna fallows or in rotation led to significant increase in crop yield.

In spite of the benefits derivable from the use of mucuna in crop production, the adoption of mucuna-based soil management by farmers has not been realized in many parts of Africa. One of the factors responsible for this is where to appropriately place mucuna in the cropping systems. Crop rotation and mucuna fallowing has been widely exploited; but recently, few farmers in some parts of Ghana and the Republic of Benin have adopted it to control obnoxious weeds.

Maize is widely grown in the West African sub-region and, under favourable conditions, it can be cropped twice a year and would benefit greatly from mucuna when planted as relay. However, farmers still find it difficult and uneconomical to prepare land and plant it to mucuna purposely to manage soil fertility.

The purpose of this study was to examine the appropriate period to integrate mucuna in the maize-based cropping system for sustainable crop production under intensive farming.

Materials and methods

Field trials were carried out for 3 years between 1995 and 1999 on loam sand of Iwo series (Rhodic haplustalf), at the Crop Research Station of the Institute of Agricultural Research and Training, Ibadan, in southwestern Nigeria. The experimental site had earlier been cropped consecutively for 4 years with maize and maize-cassava before the trials started. Table 1 shows the physical and chemical properties of the soil before cropping.

In Experiment I, maize variety TZSR-Y was intercropped with mucuna at different stages of growth. Mucuna seeds were sown 1m apart within rows of maize at 0 (at planting), 2, 4, 6 and 8 weeks after planting (WAP). Plant spacing for maize was 75 cm × 25 cm with one plant per stand, which amounted to a population of about 53,000. The plot size was 5 m × 4 m. At rates of 0, 50, and 100 kg N/ha, NPK (20-10-10) was applied, as required, to some plots by side dressing maize plants at 2 WAP. The design of the experiment was randomized complete block (RCB) with four replications. The mucuna biomass was incorporated into the soil before planting of maize in the second cropping season. In the 3rd year, the same treatments were repeated as for the previous cropping. The residual effects of the treatments on soil fertility and maize yield were studied. In the residual study, no fertilizer was applied and mucuna was not interplanted with maize. Post-harvest soil was sampled and analysed.

TABLE 1

Physical and Chemical Properties of Soil Before Cropping

Soil property	*Expt 1*	*Expt 2*
*p*H	5.6	6.2
Sand, g/kg	830	880
Silt, g/kg	75	70
Clay, g/kg	95	50
Organic C, g/kg	4.9	6.2
Exch. Ca, Cmol/kg	1.03	2.15
Exch. Mg, Cmol/kg	0.68	0.72
Exch. K, Cmol/kg	0.4	0.31
ECEC, Cmol/kg	2.56	3.42
Total N, g/kg	0.41	0.74
Avail. P, mg/kg	7.3	6.8

Another trial was conducted for 3 years as a follow-up on an adjacent site in the same location to validate the results (optimum treatment) for the previous trial on a larger plot. Maize was planted in larger plots of 10 m × 8 m each. Basal fertilizer in the form of NPK (20-10-10) at 100 kg N/ha was applied to maize 2 WAP. Mucuna seeds were sown under maize at 6 WAP. Maize was harvested at maturity. In the two cropping seasons that followed, mucuna biomass was incorporated into the soil and NPK (20-10-10) at 0, 50, and 100 kg N/ha was applied to maize at 2 WAP. The treatments were randomized within block and replicated four times.

Pre-crop and post-harvest surface soil (0-15 cm depth) samples were collected and analyzed in the laboratory for physical and chemical properties, using a standard procedure described in the laboratory manual of the International Institute for Tropical Agriculture (IITA, 1981). Maize leaf samples were collected randomly per plot, dried in the oven at 65 °C, and ground to pass a sieve of 60 mesh. Sub-samples were analyzed in the laboratory for total N, P, and K (IITA, 1981).

Results

Experiment I

Soil properties. The soil was low in fertility (Table 1). However, the level of exchangeable K was adequate. Some chemical properties improved slightly at post-harvest (Table 2). The results of the residual effect of the first cropping on soil properties showed that organic C, exchangeable Ca and Mg on the mucuna plot increased by 73, 53 and 16 per cent, respectively, when compared with values on the chemically fertilized plots. Also, organic C increased by 81 per cent, exchangeable Ca by 53, and Mg by 24 over the control (no fertilizer). However, in the 3rd year (at pre-crop soil sampling), organic C increased by 81 per cent, exchangeable Ca by 14, and Mg by 28 on the mucuna plot over the control. Also, the total N

TABLE 2

Residual Effect of Mucuna Interplanted with Maize on Soil Properties

	Post-harvest I				Post-harvest II			
Soil property	0 kg N/ha	50 kg N/ha	100 kg N/ha	Mucuna	0 kg N/ha	50 kg N/ha	100 kg N/ha	Mucuna
*p*H	5.7	5.7	5.6	5.9	5.5	5.4	5.4	5.8
Sand, g/kg	840	830	845	830	860	835	855	840
Silt, g/kg	80	80	85	100	80	80	75	90
Clay, g/kg	80	90	70	70	60	85	70	70
Organic C, g/kg	4.7	4.8	5.2	8.5	4.8	4.9	4.9	8.7
Exch. Ca, Cmol/kg	1.21	1.19	1.22	1.84	1.45	1.42	1.38	1.65
Exch. Mg, Cmol/kg	0.72	0.77	0.77	0.89	0.58	0.65	0.68	0.74
Exch. K, Cmol/kg	0.35	0.32	0.38	0.38	0.32	0.35	0.36	0.33
ECEC, Cmol/kg	2.55	2.57	2.63	3.42	2.57	2.65	2.7	3.02
Total N, g/kg	0.51	0.52	0.61	0.91	0.46	0.58	0.58	0.86
Avail. P, mg/kg	7.4	7.6	7.2	8.5	6.2	6.7	7.5	8.9

I – 1st cropping; II – 2nd cropping

and available P on the mucuna plots showed 48 and 25 per cent increase, respectively, over the control.

Grain yield. Maize yield was influenced by the treatments (Table 3). The application of 100 kg N/ha NPK (20-10-10) had the highest grain yield of 2.85 t/ha in the first cropping. The yield was not significantly different from applying 50 kg N/ha plus undersowing mucuna at 6 and 8 WAP. Undersowing of mucuna without addition of chemical fertilizer had a yield of 1.31 t/ha, about half of the yield that was recorded from applying 100 kg N/ha. The application of 50 kg N/ha significantly increased yield from 1.52 to 2.15 t/ha compared with control. The difference (P>0.05) between the yields from control and undersowing with mucuna without applying fertilizer was not significant. Likewise, these were in turn not different from applying 50 kg N/ha and undersowing of mucuna at 2 WAP.

However, yield increase was observed when planting of mucuna was delayed. At 4 WAP, the yield increased by 25 per cent over the 2 WAP and at 6 WAP, the yield increased by 44 per cent. Again, at 6 and 8 WAP, the yield increase over planting of mucuna at 0 WAP was 50-62 per cent.

TABLE 3

Effect of Mucuna Intercropped with Maize on Maize Yield

Treatment	Yield I, t/ha	Yield II, t/ha
Control	1.52c	0.85c
50 kg N/ha	2.15b	0.82c
100 kg N/ha	2.85a	1.02bc
M0	1.31c	1.38b
M0 + 50 kg N/ha	1.61c	1.45ab
M2 + 50 kg N/ha	1.8bc	1.49a
M4 + 50 kg N/ha	2.02b	1.48a
M6 + 50 kg N/ha	2.62a	1.52a
M8 + 50 kg N/ha	2.43ab	1.51a

Figures having the same letters within a column are not significantly different at P = 0.05; M - Mucuna
M0, M2, M4, M6, M8 – Planting of mucuna at planting of maize, 2, 4, 6, and 8 weeks after planting.
I - Average yield at first croppings (1st & 2nd year)
II -Yield from residual cropping (3rd year)

The results from the residual effect of the applied treatments on maize yield showed that incorporating mucuna which was undersowed with maize had significantly higher yield (about 61% increase) than applying mineral fertilizer alone (P<0.05). However, the difference between the various periods of planting mucuna was not significant.

Experiment II

The soil at pre-crop sampling was sandy in texture and low in fertility (Table 1). Some chemical characteristics of the soil improved slightly as a result of planting of mucuna in maize plot at 6 WAP (Table 4). The residual soil nutrients due to application of 50 kg N/ha were not different from those due to applying 100 kg N/ha.

The application of mineral fertilizer to maize in addition to incorporating mucuna biomass increased the height and biomass of maize for two cropping seasons (Fig. 1a, 1b). The application of 50 and 100 kg N/ha increased the biomass by 23 and 29 per cent, respectively, over incorporation of mucuna alone. The height also increased by 18 and 25 per cent, respectively, over treatment with mucuna.

Fig. 1c shows the grain yields of maize as influenced by complementary application of fertilizer with incorporation of mucuna into

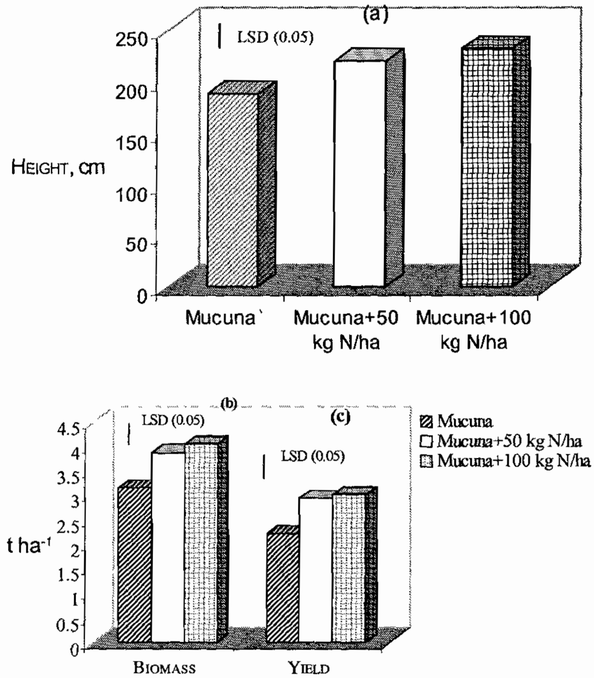

Fig. 1. Effect of application of mucuna biomass and chemical fertilizer on height (a), plant biomass (b), and grain yield (c) of maize.

Table 4

Residual Effect of Mucuna Undersowed in Relay with Maize on Soil Properties

Soil property	*Post-harvest I* 0 kg N/ha	*Post-harvest I* 50 kg N/ha	*Post-harvest I* 100 kg N/ha	*Post-harvest II* 0 kg N/ha	*Post-harvest II* 50 kg N/ha	*Post-harvest II* 100 kg N/ha
pH	6.1	6.2	6.2	6.1	6.1	6.1
Sand, g/kg	880	870	880	895	870	865
Silt, g/kg	60	70	70	55	85	75
Clay, g/kg	60	70	50	50	45	60
Organic C, g/kg	6.3	6.1	6.3	6.1	6.5	6.4
Exch. Ca, Cmol/kg	2.31	2.28	2.36	2.25	2.35	2.28
Exch. Mg, Cmol/kg	0.65	0.73	0.71	0.72	0.78	0.73
Exch. K, Cmol/kg	0.28	0.32	0.31	0.32	0.32	0.33
ECEC, Cmol/kg	3.48	3.56	3.62	3.44	3.65	3.62
Total N, g/kg	0.72	0.78	0.78	0.72	0.83	0.81
Avail. P, mg/kg	6.5	6.3	7.2	6.8	7.5	7.4

I – 1st cropping; II – 2nd cropping

the soil. The difference in maize yield between the fertilizer and unfertilized treatments (control) was highly significant . The yield increased by about 31 per cent over the control. However, the difference between 50 and 100 kg N/ha was not significant .

The application of 100 kg N/ha increased the concentration of N and P in the leaf tissue (Fig. 2). It increased the N and P concentrations by 21 per cent each over 50 kg N/ha, which in turn showed 20 and 73 per cent increase, respectively, over incorporation of mucuna alone without fertilizer application to maize.

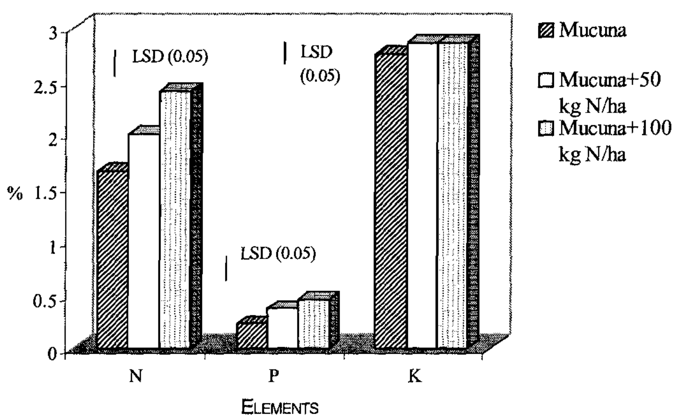

Fig. 2. Effect of application of mucuna biomass and chemical fertilizer on N, P and K in the leaf tissue of maize.

Discussion

Mucuna has a spreading/trailing growth ability which can ensure a good cover in 2 or 3 months. Therefore, a possible interference of the legume with maize was envisaged. Observations showed that undersowing mucuna on maize plot at 0 WAP had a highly negative impact on the performance of maize. Early planting of mucuna (at 0, 2 and 4 WAP of maize) caused poor yield. This could be due to high competition between the mucuna and maize for light, nutrients, and water from early stage of growth. Also, mucuna trailed on corn stalks and caused lodging of many of them. However, the application of fertilizer to maize improved growth; hence, a better crop performance. The difference (P>0.05) between the residual effects of mucuna interplanted at the various periods on maize yields was not significant. Likewise, the soil fertility levels did not differ from each other.

The positive impact which the cover crop might have had on weed suppression, soil moisture retention, reduction of surface runoff and erosion as observed by Okigbo & Lal (1977), Akobundu (1980), and Wilson *et al.* (1982) did not increase yield in this study. The widespread and suppressing nature of mucuna on the associated crop could have caused the low maize yields recorded from early planting of mucuna. Therefore, it was not surprising that at 6 and 8 WAP of maize, mucuna had highly positive results. The sowing of mucuna at this stage (tasseling) highly reduced suppression of maize plants by mucuna. By the time mucuna started trailing on the stalks, maize was reaching maturity stage. In the next 2 months after harvesting, the whole field was covered by dense, green mucuna vegetation, which was fully widespread on the ground surface. The planting of mucuna at late season ensured a full ground cover on the field during the dry season. This would reduce heat caused by solar radiation, provide better soil moisture, and enhance microbial activities in the soil.

Early studies indicated positive results from mucuna rotation and fallowing (Van Noordwijk *et al.*, 1995; Becker & Johnson, 1998; Tian & Kang, 1998; Tian *et al.*, 1999). However, adoption of the crop in the farming system for soil management is still at its low level in Africa. To reduce the problems which mucuna poses in crop rotation and fallow systems, undersowing of mucuna in relay with maize would probably be a good practice that would permit easier adoption by farmers. This practice involves zero tillage and does not require allocating land to planting mucuna alone. It could be practised annually in a maize-based cropping system and possibly extended to cereal crops like sorghum and millet.

When mucuna biomass was incorporated into the soil, application of minimal dose of fertilizer had higher effects on crop performance than when mucuna was solely incorporated into the soil. This suggests that undersowing of mucuna and fertilizer application could complement each other in improving soil fertility and increasing crop yield. However, supplementation with 50 kg N/ha had higher yield than using 100 kg N/ha, which was the rate recommended for maize in southwestern Nigeria.

Recommendation

Mucuna, a leguminous cover crop, is recommended to be undersowed with maize at 6 WAP of maize. The crop remains on the field after harvesting of maize and serves as a protective cover for soil against environmental hazards. Incorporating mucuna biomass into the soil improves soil fertility and crop yield. It is desirable to supplement the incorporation of mucuna biomass with application of chemical fertilizer at 50 kg N/ha for optimum yield of maize.

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