Rotational Effects Of Legumes On Maize Yield

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ABSTRACT: - Application of inadequate quantities of fertilizers limits maize yield in Ghana. Experiments were conducted to determine the effect of *Mucuna pruriens*, *Canavalia ensiformis*, and soybean (*Glycine max* (L.) Merrill) on maize (*Zea mays* L.) grain yield under 4 mineral fertilizer N levels in a rotational system. The legumes were established in April of 1996 and 1997 at Ejura in the forest-savanna transition zone of Ghana. During August of the respective years, the vegetation on the plots was slashed with a cutlass. Maize was planted in all the plots with blanket P and K application. Fertilizer N was applied as urea at four rates (0, 30, 60 and 90 kg N/ha) to the maize in split applications at 1 and 5 weeks after planting. Mucuna and Canavalia produced more than 3 t/ha of biomass within 4 months. Mean maize grain yields after the legumes without fertilizer N were 2.3, 1.6 and 1.0 t/ha for Mucuna, Canavalia and soybean, respectively. Maize grown after legumes responded to fertilizer N and this is an indication that the legumes didn't supply the entire N required by maize for optimum yield. The highest marginal rates of return of maize grown after canavalia and soybean were at 90 kg N/ha whilst that of mucuna was at 60 kg N/ha. It was concluded that planting Mucuna and maize in rotation is the best among the systems considered in terms of monetary gain and soil organic matter addition and the application of 60 kg N/ha to maize planted after Mucuna was the most efficient management option.

Index terms: - Crop rotation, economic analysis, legumes, maize, net benefit

INTRODUCTION

The bulk of maize in Ghana is grown in the forest-savanna transition zone of the country. Two crops of maize can be grown per year in this zone. However low soil fertility is a major factor limiting crop yields. Crop rotation with legumes improves soil properties [4], [2], [9], [17] and might therefore reduce mineral fertilizer requirements of succeeding non-leguminous crops. Crop rotation also influences N use efficiency and prompt changes in various N sources, affecting availability to the plant [11]. *Canavalia ensiformis*, *Mucuna pruriens*, *Glycine max*, and *Vigna unguiculata* have been reported to potentially contribute considerable amounts of N to succeeding crops [14], [13], [12]. However, most legumes cannot provide sufficient N to meet the potential demand of maize following them in a rotational system. Codjia (1996), studying the response of maize to *Mucuna pruriens* and *Mucuna cochinchinensis* with various rates of chemical fertilizer, observed a 98% increase in maize grain yields without chemical fertilizer and a 179% increase with 51 kg N, 46 kg P and 28 kg K/ha. In experiments conducted by [3], maize grown after grain legumes (cowpea and soybean) and legume cover crops yielded 15.1-24.6% and 30.3-42.5% higher than maize-maize cropping system respectively. Asibuo (1999) also reported higher maize grain yield when he applied 45 kg N, 18 kg P and 18 kg K/ha to maize planted after *Mucuna pruriens*, groundnut and cowpea than when no fertilizer was applied. Several studies have been done on legume/maize rotation systems. However, most of these studies did not include economic analysis of the systems. The objective of the study was therefore to determine maize grain yield responses to fertilizer N as affected by preceding legume crops and economic implication of the study.

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MATERIALS AND METHODS

Three leguminous crop species (*Mucuna pruriens*, *Canavalia ensiformis*, and soybean) were grown in sequence with maize on a Lixisol at the Crops Research Institute station at Ejura (01 "22' N, 07 "23" W) from 1996 to 1997. At the beginning of the experiment in 1996, average soil chemical properties in the 0-30cm depth were as follows: 0.27 g kg/soil total N; 21.8 mg/kg Bray I P; 107.2 mg/kg available K; 7.2 g/kg soil organic matter and 6.3soil pH. The experimental design was a split plot with 3 replications /site. The main plots were leguminous crop (Mucuna, canavalia and soybean) and the sub-plots were nitrogen levels (0, 30, 60 and 90 kg N/ha). Initial land preparation was done by slashing the field with tractor mounted slasher. Seven days later Roundup (glyphosate) was applied at rate of 900g ai/ha. The legumes *Mucuna* pruriens, *Canavaia ensiformis*, and soybean (var. Anidaso) were planted in April of 2006 and 2007 seven days after herbicide application. Mucuna and Canavalia were planted at 40 cm spacing within rows and 80 cm between rows, 2 seeds per hill were maintained. The soybean was drilled in rows 75 cm apart with 5 cm between plants. In August 1996 and 1997 the vegetation on the plots were slashed using a cutlass after plant samples have been taken on each plot ($1m^2$) at ground level for biomass assessment. The sample was dried in an oven at 70^oC for 48 hours and the weight determined. The soybean was however, harvested by hand. One week after slashing, paraquat was applied at 400 g ai/ha prior to planting open-pollinated 110 day maturity maize (var. Abeleehi) variety on all the plots at a spacing of 80 cm x 40 cm. Two seeds per hill were maintained. Maize on each plot received 20 kg P and K/ha at 1 week after sowing as triple supersulfate and muriate of potash, respectively. Nitrogen (0, 30, 60 and 90 N kg/ha) in the form of urea was applied to the maize in split applications at 1 and 5 weeks after sowing. Plants from the 4 central rows were harvested at maturity for yield determination. Economic analysis was performed using the partial budget analysis]5]. The marginal rate of return (MRR) which is the increased benefit of an option as a percentage of the increased cost, was used to determine the benefits to farmers [5].

RESULTS

At the beginning of the experiment in 1996, average soil chemical properties in the 0-30cm depth were as follows: 0.27 g kg/soil total N; 21.8 mg/kg Bray I P; 107.2 mg/kg available K; 7.2 g/kg soil organic matter and 6.3soil pH. The results show that Mucuna produced 3.7 t/ha of crop residue in 4 months (Table 1). Canavalia produced a comparable amount of biomass during the same period. However, soybean left an insignificant amount of crop residue on the soil because the entire plants were harvested and taken from the field as done by farmers. Growing maize after Mucuna was significantly better ($P<0.01$) than after Canavalia or soybean in 1996 and 1997 in terms of grain yield (Table 1). The mean grain yield of maize after Mucuna was 100% higher than after soybean and 40% higher than Canavalia in 1996. In 1997, maize grain yield after Mucuna was 55% higher than soybean and 41% higher than Canavalia. Application on N fertilizer generally resulted in increased maize grain yield regardless of the preceding legume. The mean grain yield increase was 31%, 56% and 81% when 30 kg, 60 kg and 90 kg of N fertilizer respectively were applied (Table 2). Maize planted after Mucuna without inorganic fertilizer N produced a mean grain yield of 2.4 t/ha and 2.2 t/ha in 1996 and 1997 respectively (Tables 3 and 4). Maize planted after soybean produced the lowest grain yield of 1.14 t/ha in 1996 and 0.86 t /ha in 1997 when no fertilizer N was applied. The equivalent yields after canavalia were 1.6 t/ha and 1.5 t/ha. Maize grain yields after Mucuna were significantly ($p<0.05$) higher than after Canavalia or soybean in 1996 and 1997 (Table 1). Maize grain yields after the legumes without fertilizer N was highest on plots previously planted to Mucuna. Without fertilizer N, yields after mucuna was 110% and 155% higher than after soybean in 1996 and 1997 respectively (Tables 3 and 4). At 90 kg N/ha maize after mucuna yielded 40% and 79% higher than maize after soybean in 1996 and 1997 respectively. The net benefits derived from the treatments are presented in Tables 5-7. The net benefits of Mucuna treatments at all fertilizer N levels were the highest. The marginal rate of return of the change from 60 kg N/ha to 90 kg N/ha was the highest when maize followed Canavalia and soybean. For Mucuna plots, the increase from 30 kg N/ha to 60 kg N/ha was highest (Tables 5-7).

DISCUSSION

Mucuna and Canavalia produced substantial amount of organic matter to the soil which covered the soil surface and might have reduced direct sun rays on the soil surface thereby conserving soil moisture for crop growth and development. The results are similar to what [8] obtained when they planted Canavalia in rotation with maize and produced above-ground biomass up to 5357 kg/ha. Mucuna biomass production in this study was however substantially lower than the 5.9 t/ha - 8.8 t/ha reported by [15] after growing the crop for 40 weeks. The poor yield of maize following soybean may be attributed to the way the crop was harvested. Farmers pull the whole plant and dry at home before the threshing is done. The seeds are then kept whilst the vegetative material is thrown away. Thus, plots previously planted to soybean had little stover, which is necessary for moisture conservation especially during the minor cropping season, when the growing period is short due to fewer rainy days. Also, considerable amount of N stored in the seed and stover did not return unto the soil therefore leading to mining of soil nutrients. The young pods of Canavalia and Mucuna were returned to the soil as well as vegetative parts which protected the soil surface. The stubble and the pods also served as a store of nutrients which are released to benefit the subsequent maize crop and improve the organic matter level of the soil. Ibewiro *et al*. (2000) showed in a study that different plant residues differ in rate of decomposition and release of plant nutrient. In this study, mucuna residue decomposed rapidly losing more than 60% of dry weight within 28 days. In contrast imperata decomposed slowly with only 25% of its dry matter lost in 56 days. At 28 days mucuna had released 154 kg N ha^{-1} in in-situ mulch systems representing more than 50% of its N. Cobo *et al*. (2002) studied nutrient release of 12 plant materials and found that after 20 weeks, the leaves of *Mucuna* released the highest amounts of N and P (144.5 and 11.4 kg ha^{-1}, respectively). Canavalia produced quite substantial biomass but the woody nature of the stem and the branches might have taken longer than a single cropping season to decompose. Application of fertilizer N generally increased maize grain yield. This is due to the fact that the legumes did not leave appreciable amounts of N for succeeding crop and also mineralization from the legume residue were slow. This agrees with the findings of [1], who reported that application of inorganic fertilizers to maize preceding groundnut, cowpea and Mucuna resulted in higher grain yield than plots which received no fertilizer. The results indicated that supplementary N is required by maize when it follows legumes sequentially. The net benefits of Mucuna treatments at all fertilizer N levels were the highest. From the net benefits calculated, Mucuna as a preceding crop was better than Canavalia and soybean since the net return was highest. The farmer stands to achieve good returns at the level where the rate of return is highest. The marginal rate of return of the change from 30 kg N/ha to 60 kg N/ha was the highest when maize followed Mucuna. The most profitable treatment to recommend to farmers when maize follows Mucuna at 60 kg N/ha followed by Soybean at 90 kg N/ha Canavalia at 90 kg N/ha. From the net benefits calculated, Mucuna as a preceding crop was better than Canavalia and soybean at all fertilizer N levels. The farmer stands to achieve good returns at the level where the rate of return is highest. These treatments are accepted if we assume a cut-off rate of 50% to cover the cost of capital and risk. Even though soybean produced grain, the net benefit was lower than that of Mucuna at all levels. Results of this study are in agreement with findings of [16] who studied 4 cropping systems and found that cover cropping is the most profitable with US$238 in gross margin. We conclude that planting Mucuna and maize in sequence was the best system among the three in terms of monetary gain and the potential to improve soil organic matter level.

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Table 1: The amount of biomass (t/ha) returned to the soil and subsequent maize grain yield (t/ha) by preceding legume crop.

Preceding crop	1996		1997	
	Biomass	Grain yield	Biomass	Grain yield
Mucuna spp.	3.7	2.8	4.4	3.1
Canavalia	3.5	2.0	4.0	2.2
Soybean	-	1.4	-	2.0
CV (%)	-	26.2	-	18.4
SED(0.05)	-	0.4	-	0.3

Table 2: Mean effect of preceding legume and inorganic nitrogen fertilizer (kg/ha) on maize grain yield (t/ha).

N level	Maize Grain yield		Mean grain yield	% increase over control (0 N)
	1996	1997		
0	1.4	1.8	1.6	-
30	1.8	2.3	2.1	31
60	2.3	2.6	2.5	56
90	2.6	3.1	2.9	81
CV (%)	26.2	18.4	-	-
SED(0.05)	0.3	0.3	-	-

Table 3. Effect of nitrogen and preceding crops on yield of maize (t/ha) 1996.

N level	Soybean	Canavalia	Mucuna
0	1.14	1.6	2.4
30	1.82	2.28	2.84
60	2.0	2.0	3.42
90	2.7	2.84	3.8
CV (%)	13.4	12.8	16.2
SED(0.05)	0.32	0.24	0.31

Table 4. Effects of nitrogen level on yield of maize (t/ha) 1997

N level	Soybean	Canavalia	Mucuna
0	0.86	1.5	2.2
30	1.28	1.62	2.56
60	1.6	2.3	3.0
90	1.9	2.56	3.4
CV (%)	15.9	17.1	16.0
SED(0.05)	0.36	0.37	0.26

Table 5. Economic analysis averaged over 2 years of the effects of fertilizer application on maize preceded by Mucuna *

	Nitrogen level			
	0	30	60	90
Average yield (t/ha)	2.3	2.7	3.25	3.6
Adjusted yield (t/ha)	2.07	2.43	2.93	3.24
Gross benefit (GH Cedis)	1449	1710	2051	2268
Cost of N fertilizer (GH Cedis/ha)	0	52.17	104.34	156.51
Cost of fertilizer application (GH Cedis/ha)	0	20	20	20
Total cost that vary (GH Cedis/ha)	0	72.17	124.34	176.51
Net benefit (GH Cedis/ha)	1449	1628.83	1926.66	2091.49
Marginal rate of return (%)	-	249	570.9	315.9

Table 6. Economic analysis averaged over 2 years of the effects of fertilizer application on maize preceded by Canavalia.

	Nitrogen level			
	0	30	60	90
Average yield (t/ha)	1.55	1.98	2.15	2.7
Adjusted yield (t/ha)	1.40	1.78	1.94	2.43
Gross benefit (GH Cedis)	980	1246	1358	1701
Cost of N fertilizer (GH Cedis/ha)	0	52.17	104.34	156.51
Fertilizer application (GH Cedis/ha)	0	20	20	20
Total cost that vary (GH Cedis/ha)	0	72.17	124.34	176.51
Net benefit (GH Cedis/ha)	980	1173.83	1233.66	1524.49
Marginal rate of return (%)	-	268.6	114.7	557.5

* Exchange rate : GH Cedis 1.90=1US$

Table 7. Economic analysis averaged over 2 years of the effects of fertilizer application on maize preceded by soybean*

	Nitrogen level			
	0	30	60	90
Average maize yield (t/ha)	1.0	1.394	1.8	2.3
Average soybean yield (t/ha)	0.8	0.8	0.8	0.8
Adjusted maize yield (t/ha)	0.9	1.255	1.62	2.07
Adjusted Soybean yield (t/ha)	0.72	0.72	0.72	0.72
Gross benefit of maize (GH Cedis/ha)	630	878.50	1134	1449
Gross benefit of soybean (GH Cedis/ha)	504	576	576	576
Total gross benefit (GH Cedis/ha)	1206	1454.50	1710	2025
Cost of N fertilizer (GH Cedis/ha)	0	52.17	104.34	156.51
Fertilizer application (GH Cedis/ha)	0	20	20	20
Cost of harvesting soybean (GH Cedis)	80	80	80	80
Cost of transporting soybean (GH Cedis)	20	20	20	20
Cost of threshing and shelling (GH Cedis)	25	25	25	25
Total cost that vary (GH Cedis/ha)	125	197.17	249.34	301.51
Net benefit (GH Cedis/ha)	1081	1257.33	1460.66	1723.49
Marginal rate of return (%)	-	244.3	389.7	503.7

*Exchange rate : GH Cedis 1.90 =1US$.