World Journal of Agricultural Sciences 6 (6): 720-727, 2010
ISSN 1817-3047

Residual Effect of *Mucuna pruriens* Green manure Application Rate on Maize (*Zea mays* L.) Grain Yield

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Abstract: Maize grain yield is constrained by inadequate supply of nitrogen caused by insufficient application of fertilizers that are found to be costly and unaffordable in smallholder farming. Therefore there is need to search for locally available and potentially low-cost N sources. Beneficial residual effect from mucuna biomass application during subsequent cropping seasons of maize, hence fertilizer saving, is considered one of the possible solutions. However, there are residual aspects of herbaceous legume green manure application that are not clear and warrant further investigation: The application rate of green manure biomass required to make substantial residual effect on yield of maize produced in subsequent cropping seasons is unknown. The effect of mucuna green manure application rate on seasonal persistence of the residual influence is not adequately described. Consequently, on-farm research was carried out in southwest Kenya in the period 2002-2005. The objective was to determine residual effect of mucuna green manure application rate on maize grain yield during the subsequent first and second cropping seasons after incorporation. Treatments investigated were: mucuna green manure applied at rates of 0, 30, 60, 120, 240 and 480 kg N ha^{-1}; and inorganic fertilizer-urea at 30, 60 and 120 kg N ha^{-1}. At tissue N concentration of 1.6 to 2 % for mucuna, the application rates worked to 1.5, 3, 6, 12 and 24 t DM ha^{-1} equivalent of its green manure biomass. Randomized complete block design with three replications was used and maize variety H614 planted. Data was collected on maize grain yield at harvest. Genstat discovery edition 2 was used in data analysis. Results obtained showed that mucuna green manure and inorganic fertilizer-urea N do not have residual effect on maize grain yield during the first and second subsequent planting seasons, regardless of the rate applied. These being wide range of mucuna application rates, 1.5 to 24 t DM ha^{-1}, would suggest that change in tissue N concentration of the herbaceous legume, while other factors remain similar, would have little if any dramatic alteration on the observed residual response trend.

Key words: Residual effect · Mucuna green manure · Maize

INTRODUCTION

Warren [1] defines residual effect as the current increase in yield caused by fertilizer applied in earlier seasons. Rowell [2] describes it as responses to fertilizer after the first season of application. Gomez [3] explains it as the effect, on the current crop, of fertilizer applied to previous crops. Warren [1] considers the attribute as a rather loose way of indicating benefit from old fertilizer application in subsequent seasons. The latter also suggests use of residual value as measure of the benefit as another alternative approach. Residual value is defined as the proportion of the fertilizer nutrient that remains in the soil and stays effective after the season of application. Both measures of benefit for old fertilizer application have their shortfalls [1]: Residual value is found to be restrictive than the common use of the term. Residual effect, though adopted in this study, can vary from year

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to year under the influence of weather and factors other than the old fertilizer, making it difficult to infer the fertilizer residual as defined. As solution, Warren [1] suggests that residual effects be measured and compared in the same year. Also, to make allowance for the inevitable fluctuations in yields between years, results can be expressed as the response to residual, either over the control (kg ha^{-1}) or as percentage of the control yield [1].

Assessment of residual effects is of benefit to smallholder farmer as it aims at reducing fertilizer input. Warren [1] stresses the need to make clear distinction between fresh and residual applications in the determination of residual effects. According to Warren [1] the only way to demonstrate residual effect is by first discontinuing fertilizer application. This is followed by, adding fresh fertilizer and cropping for a few subsequent seasons without further application. Also, some indication that the residual effect is working is given by the diminishing response to fresh application as residual builds up [1]. The presence of residual effects in N application therefore has implications on fertilizer management strategies in subsequent planting seasons.

There is indication that inclusion of legume in cropping system has residual effect on crop yields. Residual effect of fertilizer can greatly affect yields. In one experiment at the International Rice Research institute (IRRI), Gomez [3] reported 13 percent increase in yield caused by application of 120 kg N ha^{-1} to a previous crop. In a study conducted in Nigeria [4] it was observed that growing mucuna every third crop resulted in both increased and sustained maize yields. However, decomposition records of mucuna give contradictory picture probably because besides addition of N, green manure has other benefits to the soil.

There are residual aspects of herbaceous legume green manure application that are not clear and warrant further investigation: The application rate of legume green manure from mucuna that is required to make substantial residual effect on yield of maize produced in subsequent cropping seasons is unknown. The effect of mucuna green manure application rate, on seasonal persistence of the residual influence is not adequately described.

The objective of this research was to determine residual effect of mucuna green manure application rate on maize grain yield, during the first and second subsequent cropping seasons.

MATERIALS AND METHODS

Site Climatic Characteristics: Field experiments were carried out on-farm at Mosocho, Kisii district, southwest Kenya. Figure 1 shows that rainfall in the area is bi-modally distributed from February to August (long rains) and from September to February (short rain season). The two seasons have rainfall ranging from 800 to 1000 mm and 450 to 700 mm, respectively. Mean annual temperatures range from 18°C to 21°C and average minimum temperatures vary from 11°C to 14°C [5]. The experimental site area at Bokeabu village is in lower midlands zone one to two (LM$_1$-$_2$) and has characteristics as described in FURP [5]. Variability in the total decadal rainfall amongst planting seasons and with regard to on-set, planting date, distribution and plant phenology at the experimental site is illustrated in Figure 1.

Site Characterization: Standard methods were used to describe soil physical and chemical characteristics [6]. Mechanical analysis using the hydrometer method showed that soils are of the sandy clay textural class (Table 1). Soil water reaction was determined by glass electrode method. The pH (water) was strongly acid in the range of 5.0 to 5.9 that can result in satisfactory growth but with drop in maize yield. The pH range of 5.0 to 5.9 is below 6.6 to 7.3 considered neutral and optimum for crop growth and yield. The percentage total N was measured using Kjeldahl method. Total N level obtained was less than 0.2 % and therefore considered low. Organic carbon determined using the Walkley and Black method was highest in 0-15 cm with value of 2.18 % classified as medium. Mehlich method was used in extracting available phosphorus (P), while ammonium acetate was used to extract exchangeable bases (Ca^{2+}, Mg $^{2+}$, K $^{+}$and Na).$^{+}$ Phosphorus (P) was determined calorimetrically using UV spectrophotometer (UVS). The first two cations were measured using flame photometry by atomic absorption spectrophotometer (AAS). The other two were determined using a flame photometer.

Phosphorus level was 8.5 ppm at 0-15 cm, which is low as it is less 20 ppm according to Mehlich [5]. Potassium amount was 1 cmol kg^{-1} at 0-15 cm that is considered adequate. Calcium was low at all depths, as values obtained were less than 2 cmol kg^{-1}. Cation exchange capacity (CEC) determined by ammonium saturation method ranged from 10.4 cmol kg^{-1} at 0-15 cm depth to 11.4 cmol kg^{-1} at 15-30 cm which indicates low

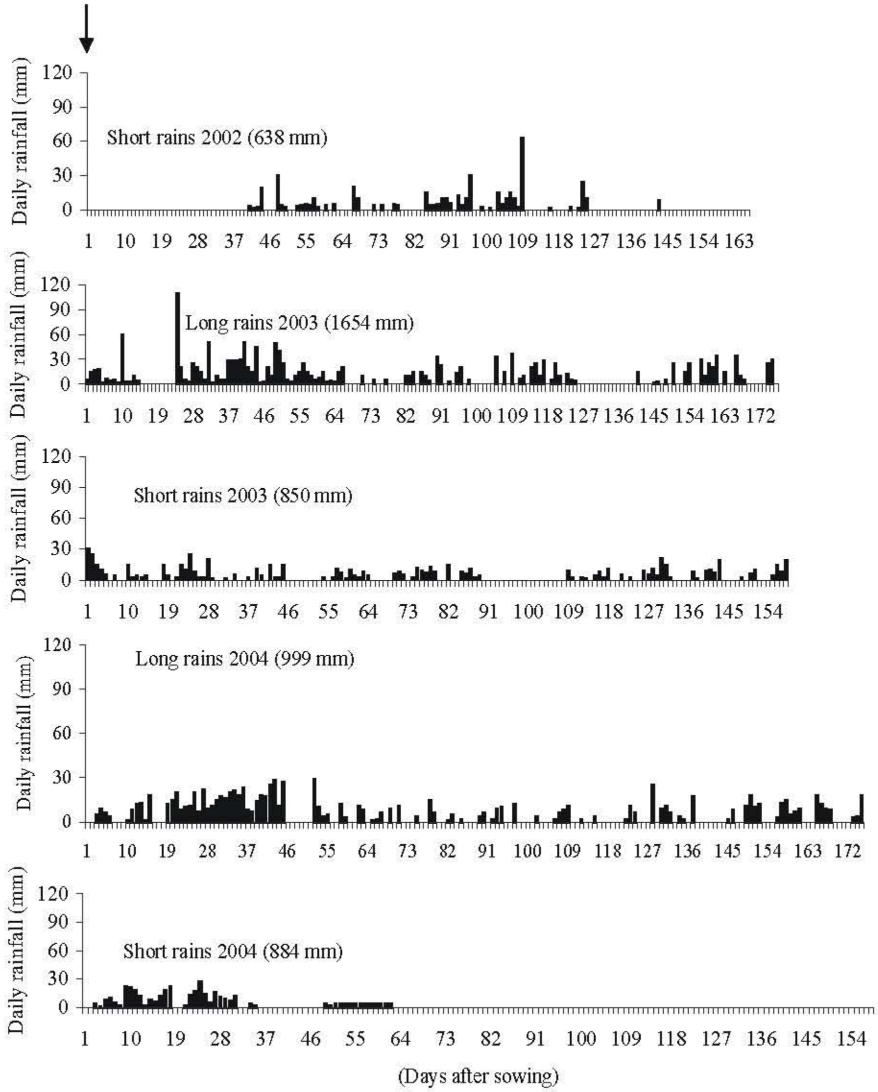

Fig. 1: Variability of daily rainfall during planting seasons at Bokeabu village, Mosocho, Kisii, southwest Kenya. Long rains season (LR) = March to September; Short rains season (SR) = September to March. (Phenological stages: vegetative development = 1 to 77 days, reproductive = 77 to 84 days, kernel development and maturation =91 to 112 days, maturation and drying = 119 to 154 days in SR or 172 in LR.). Data at start of SR 2002 and end of LR 2004 are missing.

nutrient availability as values range between 6 to 12 cmol kg^{-1}. Low CEC values result in a small capacity for soil to hold nutrient cations that together with leaching caused by high rainfall may lead to deficiencies. Soil type is nito-humic ferralsol [5] and is of low to medium inherent fertility, as its CEC value is less than 15 cmol kg^{-1} and base saturation 57 to 60 % (Table 1) [5].

Mucuna Green Manure Biomass Characterization: Mucuna green manure characterization was done on composite sample. It was assumed that mucuna biomass would be applied as produced, irrespective of its plant part composition. The nutrient concentration in the composite sample was 46% C, 1.6% N, 0.36% Ca, 0.16 Mg and C:N ratio 21.

Experimental Design: Mucuna green manure was applied at 0, 30, 60, 120, 240 and 480 kg N ha^{-1}; and inorganic fertilizer-urea at 30, 60 and 120 kg N ha^{-1}. The mean tissue N concentration in mucuna was 1.6 % hence mucuna dry matter (DM) was 0, 1.5, 3, 6, 12 and 24 t DM ha^{-1}, respectively. These corresponded to 0, 19, 38, 76, 152 and

Table 1: Physical and chemical properties of soil in field experimental site at Mosocho, southwest Kenya [1]

		Soil depth (cm)				
Parameter Measured	Units	0-15	15-30	30-50	50-100	[2] critical values and classification.
Particle size						
- Sand	%	46	40	46	40	
- Silt	%	8	10	8	8	Sandy clay soil
- Clay	%	46	50	46	52	
Bulk density	g cm^{-3}	1.0	1.1	1.1	1.1	
pH (ratio 1:2.5) H_2O		5.1	5.9	5.2	5.6	(5.0-5.9)
1 N KCl		4.2	4.6	4.5	4.9	Strongly acid
Organic matter (O.M)	%	3.8	2.8	2.3	1.7	(2.1-4.2) Medium
Organic carbon (O.C)	%	2.2	1.6	1.3	1.0	(1.6-2.0) Medium
Total nitrogen (N)	%	0.18	0.14	0.07	0.05	(< 0.2) Low
C: N ratio		12	12	19	19	(< 20) Low
Avail. Phosphorus						
(Mehlich method)	ppm	8.5	1.5	0.25	0.22	(<20) Low
Avail. Potassium (K)	Cmol kg^{-1}	1.00	0.95	0.20	0.15	(0.2-1.5) Adequate
Calcium (Ca)	Cmol kg^{-1}	0.55	0.45	0.23	0.30	(< 2.0) Low
Magnesium (Mg)	Cmol kg^{-1}	4.7	5.15	5.15	3.35	(>3.0) Excessive
Sodium	Cmol kg^{-1}	0.01	0.01	0.01	0.01	(< 2.0) Adequate
Base saturation						
(Ca^{2+}, Mg^{2+}, K^+ and Na)	%	60	58	47	30	(40-85) Medium [5]
CEC	Cmol kg^{-1}	10.4	11.4	11.8	12.6	(6-12) Low
Overall					Low to medium inherent fertility soil	

[1] To convert Cmol kg^{-1} to ppm (mg l^{-1}): Multiply by 1000 x atomic weight [6].

To convert % to ppm (mg l^{-1}): divide by 10,000.

[2] Landon, J. R. 1984. Booker tropical soil manual: A handbook for soil survey and agricultural land evaluation in the tropics and sub-tropics. Longman Inc, New York, U.S.A. 450p.

Table 2: Field experimental schedule showing mucuna application seasons and, the first and second subsequent seasons during which maize was planted and residual effects of the various treatments evaluated[?]

	Experiment: Subsequent Seasons							
	Dates			Dates			Dates	
Application season	Planting	Harvest	First Depletion	Planting	Harvest	Second Depletion	Planting	Harvest
1 Short rain 2002 (S1)	20-9-02	3-3-03	-					
2 Long rain 2003 (S2)	21-3-03	11-9-03	Long rain 2003 (S1R1)	21-3-03	11-9-03	-		
3 Short rain 2003 (S3)	15-9-03	19-2-04	Short rain 2003 (S2R1)	15-9-03	19-2-04	Short rain 2003 (S1R2)	15-9-03	19-2-04
4 Long rain 2004 (S4)	18-3-04	8-9-04	Long rain 2004 (S3R1)	18-3-04	8-9-04	Long rain 2004 (S2R2)	18-3-04	8-9-04
5 Short rain 2004 (S5)	18-9-04	16-2-05	Short rain 2004 (S4R1)	18-9-04	16-2-05	-		

[?] KEY

S1 = Short rain 2002, S2 = Long rain 2003, S3=Short rain 2003, S4 = Long rain 2004, S5 =Short rain 2004

S1R1 =Long rain 2003, first subsequent season, S1R2 = Short rains 2003, second subsequent season.

S2R1 = Short rain 2003, first subsequent season; S2R2 =Long rain 2004, second subsequent season.

S3R1=Long rain 2004, first subsequent season

S4R1 = Short rain 2004, first subsequent season

305 kg fresh weight of the biomass per 21 m^2 plot, in that order. The experiment was laid out, as randomised complete block design replicated four times [7]. Maize H614 was planted in plots of 3 m x 7 m, at 75 cm x 30 cm, one plant/hill and harvested. The five planting seasons in which mucuna green manure and inorganic fertilizer N were applied are short rains 2002, long rains 2002, short rains 2003, long rains 2004 and short rains 2004.

Residual Effect of Mucuna on Maize Yield in Subsequent Seasons: Table 2 shows the seasonal schedule of the experiments and planting dates. In the subsequent first and second maize planting seasons there was no mucuna green manure or inorganic fertilizer-urea N added to the soil. Applied treatments in short rain 2002 as described in the preceding section were evaluated for their residual effect on maize planted in the first and second subsequent seasons during long and short rains 2003 respectively, within the previous experimental design and plots. Treatments applied in long rain 2003 were assessed for their residual effect on maize grain yield in the first and second subsequent planting seasons during short rain 2003 and long rain 2004, in that order. Those applied in short rains 2003 were evaluated for their residual effect in the first subsequent season during long rain 2004; while those applied in long rain 2004 were similarly assessed for the effect in short rain 2004 (Table 2).

Crop Management: During the season of green manure application season, mucuna grown on a nearby plot was harvested, chopped into small pieces of about 2 cm and incorporated into the soil according to treatments prior to planting of maize on the same day. Phosphorus (P) and potassium (K) were applied as triple super phosphate and muriate of potash, respectively. All plots were supplied basally with 50 kg ha^{-1} P and K to ensure nutrients were not limiting, except for N. Nitrogen was applied as mucuna green manure basally, or inorganic fertilizer-urea in two splits: First half at one week after emergence (WAE) and second one in 3 to 4 WAE, after first weeding. The purpose of splitting was so as to minimize losses through leaching, denitrification, run off and volatilisation. During seasons of residual evaluation of the treatments, maize planting was done without fresh addition of mucuna green manure, inorganic fertilizer-urea, P or K to the plots.

Data Collection

Maize Grain Yield: Grain yield was determined from the harvest of 5.2 m^2 area in the centre of the plot. The grain was oven-dried at 105°C for 72 hours to obtain grain yield dry matter weight. Maize grain to be used in plant total N analysis was dried at 65 °C for 72 hours to constant mass.

Data Analysis: Genstat Discovery edition 2 was used in performing data analysis and significant treatment effects determined using analysis of variance at F-probability of 0.05. Treatment means found to be significant were separated using Fischers's protected least significant difference (LSD) test [7].

RESULTS AND DISCUSSION

First and Second Subsequent Planting Seasons: Effect of Planting Season: Maize grain yield varied significantly with planting season. Maize in long rain seasons had same grain yield and trend similar to that in short rains (Table 3 and 4). The variation was attributed to periodic changes in rainfall and thus soil moisture level [8]. In order to maximize maize yields soil moisture should be maintained above 50% of the available water capacity in the rooting depth of the soil profile throughout the growing season. This is not always possible as rainfall can be very scarce and sporadic. However, it is essential to at least have adequate soil moisture at the time of anthesis in order to have a full set of kernels on the maize ear at harvest time. Anthesis stage is when supplemental water through irrigation would be most beneficial.

Effect of Nitrogen Source: Maize grain yield response to source of residual nitrogen was non-significant (Table 3 and 4). This was attributed to N loss in the soil profile through leaching. Ramos [9] state that the more reduced nutrient forms such as ammonium and fertilizer-urea N is converted to nitrate in the soil quite rapidly, depending on climate and soil factors. In temperate climates, transformation of urea or ammonium fertilizers to nitrate is fast enough to prevent observing any difference in nitrate leaching.

Effect of Nitrogen Application Rate: Maize grain yield response to residual mucuna green manure was non-significant irrespective of application rate. The response to residual inorganic fertilizer-urea showed similar trend (Table 3 and 4). This was attributed to N loss in leaching. Lack of residual effect in N fertilizers has been accredited to its mobility in soil [9].

Table 3: Effect of mucuna green manure and inorganic fertilizer-urea application rate on on maize grain yield during first subsequent season, at Mosocho, Kisii, southwest Kenya (2003-04)

		Maize grain yield (t ha^{-1})				
		Long rain 2003	Short rain 2003	Long rain 2004	Short rain 2004	Season and interactions
Rainfall (mm)		1654	850	999	844	
Treatment Nitrogen (kg N/ha)						
Mucuna green manure	0	1.13	1.07	1.52	0.94	
	30	1.47	1.31	1.40	1.08	
	60	1.35	1.26	1.14	1.22	
	120	2.44	1.40	2.04	1.17	
	240	1.91	1.31	0.98	1.02	
	480	1.54	1.31	0.94	1.12	
Inorganic fertilizer-urea	30	1.21	1.47	1.36	1.40	
	60	2.18	1.63	1.67	0.91	
	120	0.95	1.06	0.93	1.12	
Mean	1.57	1.31	1.33	1.11		
Season F test						*
LSD season						0.26
N Source F test	ns	ns	ns	ns		
LSD N source	0.58	0.36	0.57	0.32		
N source x season F test						ns
LSD N source x season						0.46
N rate F test	*	ns	ns	ns		
LSD N rate	0.76	0.54	0.76	0.50		
N rate x season F test						ns
LSD N rate x season						0.69
% C.V treatment	33.2	27.2	39.1	30.8		

F=Fischer test; * =Differences significant, ns=Differences non-signifcant; LSD=Least significant difference; N source rates=30, 60 and 120 kg N ha^{-1}

Table 4: Effect of mucuna green manure and inorganic fertilizer-urea application rate on maize grain yield in second subsequent planting season, at Mosocho, Kisii, southwest Kenya (2003-04)

		Maize grain yield (t ha^{-1})		
		Short rain 2003	Long rain 2004	Season and interactions
Rainfall (mm)		850	999	
Treatment Nitrogen (kg N/ha)				
Mucuna green manure	0	1.11	1.50	
	30	1.67	1.64	
	60	1.52	1.71	
	120	1.41	1.99	
	240	1.87	1.64	
	480	1.52	1.64	
Inorganic fertilizer-urea	30	1.54	1.30	
	60	1.41	1.51	
	120	1.67	1.84	
Mean	1.52	1.64		
Season F test				ns
LSD season				0.27
N Source F test	ns	ns		
LSD N source	0.32	0.44		
N source x season F test				ns
LSD N source x season				0.32
N rate F test	ns	ns		
LSD N rate	0.70	0.79		
N rate x season F test				ns
LSD N rate x season				0.70
% C.V treatment	31.4	31.8		

F=Fischer test; * =Differences significant, ns=Differences non-signifcant; LSD=Least significant difference; N source rates=30, 60 and 120 kg N ha^{-1}

There were non-significant interaction effects between residual N, source or application rate and planting season for maize grain yield (Table 3 and 4). This was due to non-significant residual effect of the treatments on maize grain yield.

The findings of this research corroborate some reported earlier: A study by Ssali [10] on a humic nitisol in Kenya using ^{15}N isotope method showed that about 34 to 43 % of the applied N fertilizer remained in the soil and about 70 % was within the topsoil layer (0–30 cm). However, there was no significant equivalent maize grain increase in subsequent seasons, indicating no beneficial residual effect of the applied fertilizers [10]. Residual effect of legume material in Brazil was observed to be relatively small as measured either by yield increase or N uptake [11, 12]. In eastern Uganda application of 1.8 t DM ha^{-1} of biomass from tithonia failed to give significant residual effect on maize stover and yield, on sandy clay loam [13]. Failure of applied herbaceous legume biomass to have residual effect could be attributed to explanations by Kumar and Goh [14] and, Kuzyakov *et al.* [15]. The two note that residual effect of plant biomass application would depend on factors that determine its decomposition and persistence: residue physical and chemical quality; edaphic factors, soil and plant biomass management and climate. Kumar and Goh [14] and [15] provide review of the effects of these factors on decomposition of plant residues.

Lathwell [14] reported that under temperate climate, only 57 % of applied green manure remains in the soil 70 days after incorporation. Thereafter, there is little or none of the applied green manure left in the soil to cause residual effect in subsequent cropping season. Mucuna being succulent with high soluble carbohydrate and N content that stimulates microbial breakdown is expected to decompose rapidly upon application to the soil. Based on decomposition, it would therefore appear that mucuna green manure application is unexpected to have residual influence.

CONCLUSION

Herbaceous legume biomass of mucuna green manure and inorganic fertilizer-urea N do not have residual effect on maize grain yield during the first and second subsequent planting seasons, regardless of the rate applied. These being wide range of mucuna application rates, 1.5 to 24 t DM ha^{-1}, would suggest that change in tissue N concentration of herbaceous legume, while other factors remained similar, would have little if any dramatic alteration on the observed residual response trend.

ACKNOWLEDGEMENTS

The authors wish to gratefully acknowledge the following for the various roles they played in support of the research: Faculty of Agriculture, University of Nairobi, Kenya; Director, Kenya Agricultural Research Institute (KARI); Co-ordinator, Legume Research Network Project (LRNP); and Centre Director, KARI-Kisii. The Rockfeller Foundation through the LRNP and KARI are highly appreciated for financing the research work.

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