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# Effect of Mucuna Green Manure Rate Applied on Maize Grain Yield During the Application Season

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## Abstract

*Maize yield in Kenya is constrained by inadequate supply of nitrogen and there is need to search for locally available and potentially low-cost N sources. Consequently, on-farm research was carried out in southwest Kenya in the period 2002-2005. The objective was to evaluate effect of Mucuna pruriens green manure biomass application rate on maize grain yield in sandy clay soil. Treatments evaluated were: mucuna green manure applied at rates of 0, 30, 60, 120, 240 and 480 kg N ha$^{-1}$; and inorganic fertilizer-urea at 0, 30, 60 and 120 kg N ha$^{-1}$. The experimental design was randomized complete block with four replications. Results obtained showed that mucuna application rate of 30 kg N ha$^{-1}$ did not significantly improve maize grain yield. Its application at 60 kg N ha$^{-1}$ significantly increased maize grain yield only in seasons when rainfall was high notably in long rains. But, mucuna green manure applied at a rate of 120 kg N ha$^{-1}$ significantly improved maize grain yield in both short and long rain seasons when rainfall amounts received were variable. Application of mucuna green manure at higher rates of 240 and 480 kg N ha$^{-1}$ made no further significant increase in maize grain yield. Therefore, application rates lower than 120 kg N ha$^{-1}$ equivalent of mucuna green manure biomass may be inadequate and would require supplementation with inorganic fertilizer N if maize grain yield is to be increased.*

**Key words:** Maize, grain yield, green manure, mucuna, biomass, fertilizer.

## Introduction

Declining soil fertility limits maize grain yield in Kenya and nitrogen is one of the most limiting nutrients (FURP, 1994). Mucuna, a potential on-farm N legume source, has low biomass production that varies with agro-ecological and niche conditions (Mureithi and Gitahi, 2004). This limits capability of the legume to meet maize N requirement. Despite the variability in biomass productivity of mucuna, the quantity of green manure required to bring about noticeable increase in maize grain yield is unknown. Definition of the optimum amount of legume based N would make it easy to determine whether mucuna N accumulation in the production condition is adequate or less, and when supplementation with inorganic fertilizer is required in order to improve yield. Also, judicious legume biomass application would optimise N utilization for maize production and minimize N losses and pollution of water sources. Biomass quantity constraint is not confined to herbaceous legume green manure cover crops but also in hedgerow tree species. In the humid tropics, hedgerow trees produce 8 to 10 t DM $ha^{-1}$ of biomass, while those in the sub-humid tropics of Kenya give 4 to 5 t DM $ha^{-1}$ (Mugendi *et al*., 1999). Low biomass productivity is a major drawback that limits the potential of organic manure as nutrient sources. Soil organic matter has the role of supplying plant nutrients, enhancing cation exchange capacity, improving soil aggregation, and hence water holding capacity, improving soil pH, supporting soil biological activity, consequently giving higher crop yield (Cabrera *et al*., 2005).

The objective of this research was to determine effect of different application rates of mucuna green manure on maize grain yield during application season.

## Materials and Methods

### Climate of the Site

On-farm experiments were carried out at Bokeabu village of Mosocho division, Kisii district, southwest Kenya. Rainfall is bi-modally distributed from February to August (long rains) and September to February (short rain season). The long and short rain seasons have rainfall ranging from 800 to 1000 mm, and 450 to 700 mm, respectively. Mean annual temperatures range from 18$^{O}$C to 21$^{O}$C and, average minimum temperatures from 11$^{O}$ to 14$^{O}$C with a mean maximum of 25.1 $^{O}$C. The experimental area lies in lower midlands zone one to two ($LM_1$-$_2$) (FURP, 1987). Rainfall recorded at the site using rain gauge is presented in Figure 1.

### Soil characterization

Mechanical analysis using the hydrometer method showed that soils are of the sandy clay textural class (Table1). Soil water reaction determined by glass electrode method indicated that the pH (water) was strongly acid in the range of 5.0 to 5.9 which can result in satisfactory growth but with drop in 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 measured using Kjeldahl method 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. The available phosphorus (P) extracted using Mehlich method and determined calorimetrically using ultraviolet and visible spectrophotometer (UVS) was 8.5 ppm at 0-15 cm, which is low as it is less 20 ppm according to Mehlich. Ammonium acetate was used to extract exchangeable bases ($Ca^{2+}$, $Mg^{2+}$, $K^{+}$ and $Na^{+}$). The first two cations were measured using flame photometry by atomic absorption spectrophotometer (AAS). The other two were determined using a flame photometer.

Potassium amount was 1 cmol $kg^{-1}$ at 0-15 cm that is considered adequate. Calcium was low at all depths, as

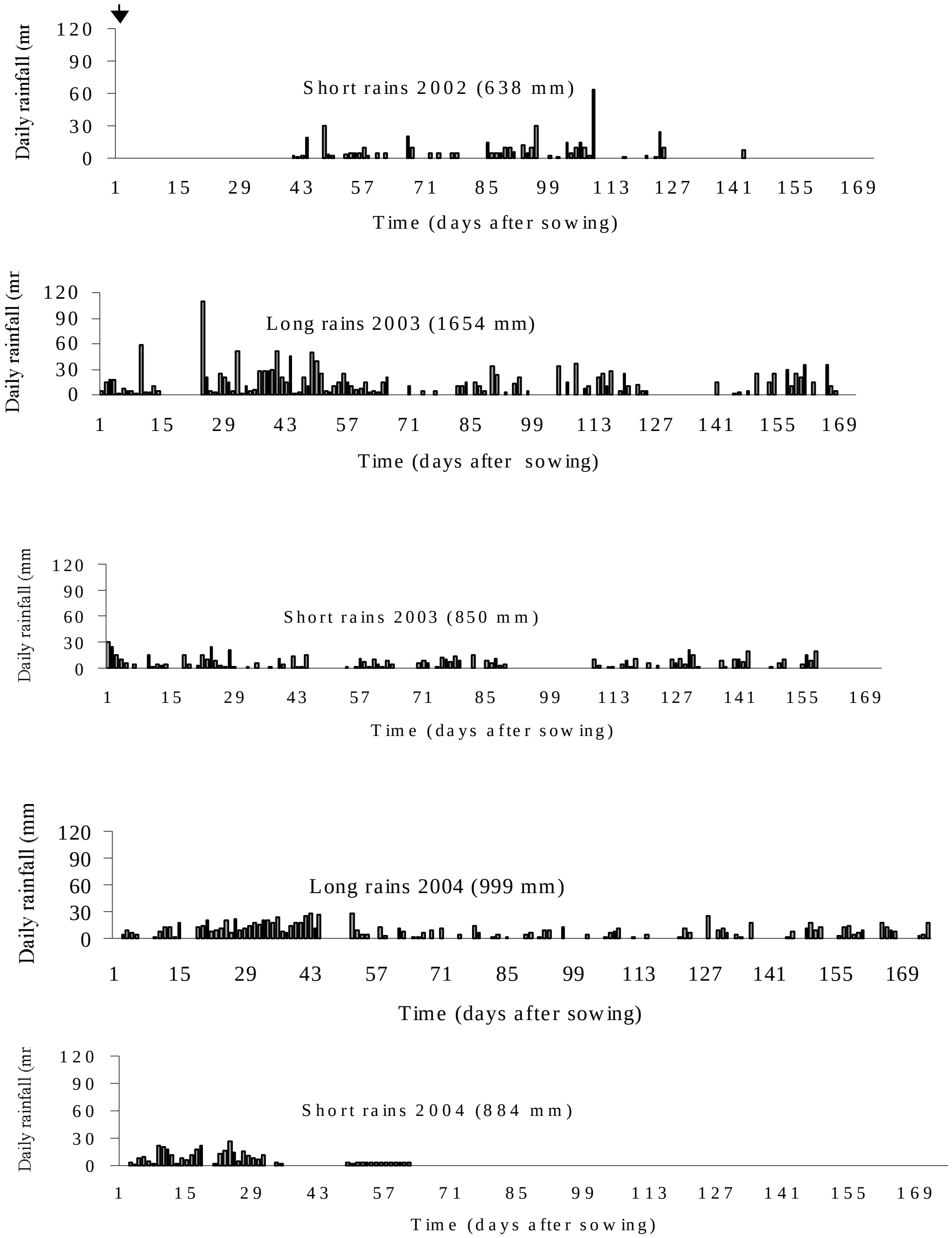


Figure 1. Variability of daily rainfall during planting seasons at Bokeabu village, Mosocho, Kisii, southwest Kenya. Long rains season (LR) = March to September; Short rains season (SR) = September to March. (Phenological stages: vegetative development = 1 to 77 days, reproductive = 77 to 84 days, kernel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

Table 1. Physical and chemical properties of soil in field the experimental site

| Parameter Measured | Units | Soil depth (cm) | | | | [2] Critical values and classification. |
|---|---|---|---|---|---|---|
| | | 0-15 | 15-30 | 30-50 | 50-100 | |
| 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) Strongly acid |
| 1 N KCl | | 4.2 | 4.6 | 4.5 | 4.9 | |
| 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 (FURP, 1987) |
| 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 (Okalebo *et al*., 2002). 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. Effect of mucuna green manure and inorganic fertilizer-urea rate used on maize grain yield during application season

| | | Maize grain yield (t ha$^{-1}$) | | | | | |
|---|---|---|---|---|---|---|---|
| | | Short rain 2002 | Long rain 2003 | Short rain 2003 | Long rain 2004 | Short rain 2004 | Season and interactions |
| Rainfall (mm) | | 638 | 1654 | 850 | 999 | 844 | |
| Treatment | | | | | | | |
| Nitrogen (kg N/ha) | | | | | | | |
| | 0 | 1.07 | 2.07 | 0.90 | 1.09 | 0.70 | |
| Mucuna green manure | 30 | 1.30 | 3.13 | 0.99 | 1.52 | 0.72 | |
| | 60 | 1.14 | 3.08 | 1.52 | 2.38 | 0.97 | |
| | 120 | 1.62 | 3.96 | 3.01 | 3.55 | 1.53 | |
| | 240 | 1.68 | 3.13 | 2.08 | 3.51 | 1.48 | |
| | 480 | 1.39 | 3.13 | 2.36 | 4.12 | 1.29 | |
| Inorganic fertilizer-urea | 30 | 1.46 | 2.83 | 1.40 | 2.41 | 0.68 | |
| | 60 | 1.55 | 3.23 | 1.42 | 2.27 | 0.90 | |
| | 120 | 1.32 | 3.59 | 1.95 | 2.07 | 0.47 | |
| Mean | | 1.39 | 3.13 | 1.62 | 2.55 | 0.97 | |
| Season (S) F test | | | | | | | * |
| LSD season | | | | | | | 0.33 |
| N Source F test | | ns | ns | ns | ns | * | |
| LSD N source | | 0.20 | 0.45 | 0.43 | 0.70 | 0.36 | |
| LSD N source rates | | | | | | 0.50 | |
| N source x season F test | | | | | | | ns |
| LSD N source x season | | | | | | | 0.44 |
| N rate F test | | * | * | * | * | * | |
| LSD N rate | | 0.35 | 0.56 | 0.53 | 1.01 | 0.47 | |
| N rate x season F test | | | | | | | * |
| LSD N rate x season | | | | | | | 0.63 |
| % C.V Treatment | | 17.3 | 11.8 | 22.6 | 27.2 | 33.3 | |

F=Fischer test; * =Differences significant, ns=Differences non-signifcant; LSD=Least significant difference; N source rates=30, 60, 120 kg N ha$^{-1}$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 nutrient availability as values range between 6 to 12 cmol kg$^{-1}$. The soil 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) (Landon, 1984). FURP (1989) classified soil of the experimental site as a nito-humic ferralsol.

**Experimental design**

Treatments 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$^{-1}$. The tissue N concentration in mucuna was 1.85 to 2 % hence the rates on dry matter (DM) basis were equivalent to 0, 1.5, 3, 6, 12 and 24 t DM ha$^{-1}$ of green manure biomass, respectively. The treatments were laid out, as randomised complete block design replicated four times (Mead *et al.*, 1983). Maize H614 was planted at 75 cm x 30 cm, at a population of one plant/hill. Data was collected on maize grain yield. The experiment was carried out for five seasons in short rain 2002, long and short rains 2003 and 2004.

**Crop management**

Mucuna green manure grown in a nearby plot was harvested, chopped into small pieces of about 2 cm and incorporated into the soil prior to planting of maize in same day. All plots were supplied basally with 27 kg ha$^{-1}$ P and K to ensure they were not limiting, and only N rate effects on maize. These were applied as triple super phosphate, and muriate of potash, respectively. Inorganic fertilizer-urea was applied in two splits: First half at one week after emergence (WAE), and second one in 3 to 4 WAE, after first weeding.

**Data collection**

Maize 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$^{o}$C for 72 hours to obtain grain dry matter weight.

**Data analysis**

Genstat was used in performing data analysis and significant treatment effects determined using analysis of variance at F-probability of 0.05. Treatments found to be significant were separated using least significant difference (LSD).

## Results and Discussion

**Maize grain yield**

Maize grain yield was significantly higher in long than in short rain season (Table 2). This was attributed to variation in seasonal rainfall whereby there was more in long than short rains. Other factors such as on-set of the rainfall and its distribution within season played some role in determining the response trend (Mburu and Gitari, 2006). The consequence of soil microbial biomass activity variations with seasonal climate and soil moisture content is that there probably are more nutrients mineralized from soil organic matter (SOM) especially N, P and S that is availed for maize in long than in short rains leading to better grain yield of the crop (Rigobelo and Nahas, 2004).

Nitrogen source did not have significant effect on maize grain yield, regardless of application rate used (Table 2). Mucuna green manure has a high N concentration of 1.8 to 2 %, which is past the 1.7% considered threshold for transition from net immobilization to net mineralization

(Wong and Nortcliff, 1995). Consequently, it might have decomposed rapidly upon incorporation in soil releasing its N, thereby making no difference with inorganic fertilizer source. Otherwise, nitrification that follows ammonium-N released from decomposition has been characterized as being so fast to extent that it might not make difference amongst different N sources (Ramos, 1996).

Grain yield response to application of mucuna N was significant. Maize with no fertilizer applied and that supplied with mucuna green manure at 30 kg N ha$^{-1}$ had comparable grain yield (Table 2). This was possibly because N supply from 30 kg N ha$^{-1}$ was not enough to trigger net N mineralization. Or it might be that the N mineralized at application rate of 30 kg N ha$^{-1}$ was not large enough to cause noticeable increase in maize yield. The observation corroborates findings by Mureithi *et al.* (2002) whereby application of 1.0 t DM ha$^{-1}$ of mucuna green manure equivalent to 27 kg N ha$^{-1}$ failed to show significant increase in maize yield on a nitisol in central Kenya.

Maize applied with mucuna at rate of 60 kg N ha$^{-1}$ showed significant increase in grain yield during long rain seasons, compared to the control. But, the treatment failed to make notable improvement in maize grain yield in short rain seasons (Table 2). This is probably because of inadequate soil moisture for decomposition and efficient utilization of N during short rains. The result suggested that mucuna green manure applied at rate of 60 kg N ha$^{-1}$ improved grain yield of maize in sandy clay only in seasons of high rainfall, possibly because N supply from the biomass quantity was not sufficient. Similar lack of significant response in maize grain yield has been observed in on-farm trials at Nyamira district of southwest Kenya: Despite incorporating a mean of 1 to 3.2 t DM ha$^{-1}$ of green manure biomass, equivalent to about 40 to 100 kg N ha$^{-1}$ from mucuna, silverleaf desmodium, crotolaria, lablab and lana vetch legumes, grain yield of maize in nitisol could not show significant increase over non-fertilized control (Maobe *et al.*, 2000). Tanimu *et al.* (2007) noted that a predictable consequence of the variable N quantities, in different application rates is that they will contribute varying amounts of the nutrient to the soil and this is likely to be reflected in the crop. Whether applied mucuna leads to N release from the soil compared to the control, would depend on C: N ratio of not only added litter, but also the SOM, and the soil microbial biomass. If the applied N-rich mucuna falls short of meeting soil microbial N requirement to utilize SOM, then the material is unlikely to make positive priming effect (Kuzyakova *et al.*, 2000). This is possibly what may have happened in the use of mucuna green manure applied at rates of 30 and 60 kg N ha$^{-1}$.

Application of mucuna green manure at rates of 120, 240 and 480 kg N ha$^{-1}$ caused consistent and significant increase in maize grain yield compared to the control (Table 2). This is unlike its application at rate of 60 kg N ha$^{-1}$

that caused significant increase in some seasons, while falling short of the same in some thereby raising doubt on its consistent superiority in N supply over the control. The result was perhaps due to superior N supply from mucuna applied at rates of 120, 240 and 480 kg N $ha^{-1}$ compared to the control. Mucuna green manure application rates in excess of 120 kg N $ha^{-1}$ showed little or no further harmonious increase at all in maize grain yield beyond. From the results, it can be said that mucuna rate of 120 kg N $ha^{-1}$ is indeed the optimum agronomic rate of the nutrient to use in cultivation of maize. At Jimma in Ethiopia, Bogale *et al.* (2001) observed that mucuna, crotolaria, and canavalia intercropped with maize produced 2.4, 0.48 and 0.84 t DM $ha^{-1}$ of biomass that had non-significant influence of 0 to 21 % on maize grain yield in the following year. Comparatively, maize grain yield was significantly increased by 50 to 134 % where the sole legumes producing 7.46, 7.99 and 3.38 t DM $ha^{-1}$ of biomass preceded it in rotation. This variation in maize grain yield response was attributed to differences in legume biomass quantities produced (Bogale *et al.,* 2001).

Maize applied with inorganic fertilizer-urea at rates of 30 and 60 kg N $ha^{-1}$ yielded significantly higher grain than the control, with exception of short rain 2004 (Table 2). This showed that maize N nutrition was better in the treatments than in the control (Table 2). The disparity in maize response to 30 kg N $ha^{-1}$ from fertilizer compared to same rate from mucuna was attributed to differences in application management of the two N sources. Whereas mucuna was applied all basally, inorganic fertilizer was split, with half being side dressed one week after emergence, and other half at 3 to 4 weeks after first weeding. The observed trend has been reported elsewhere: In a sandy soil at Mtwapa in coastal Kenya, mucuna and lablab relay-cropped with maize, and left to grow as sole after maize harvest prior to incorporation of biomass in following season, failed to make significant effect on maize grain yield during long rains 1998 (Saha and Muli, 2002). In the same experiment and season, use of inorganic fertilizer at rate of 30 kg N $ha^{-1}$ significantly increased maize grain yield by 26.7 %, and its combination with legume proved to be of no advantage (Saha and Muli, 2002). The application of inorganic fertilizer at rate of 120 kg N $ha^{-1}$ in the current study showed further significant increase in maize yield over 30 and 60 kg N $ha^{-1}$ only in good rainfall year notably, long and short rains 2003 (Table 2). The treatment either was same or worse than its application at 30 and 60 kg N $ha^{-1}$ in rest of the seasons. The reason for the higher response is the high N addition involved in the treatment compared to the fertilizer applied at lower levels of 30 and 60 kg N $ha^{-1}$. The variability with season suggests that application of such high fertilizer level would be meaningful only in long rains when adequate soil moisture might be expected. Application of mineral N fertilizers may influence biologically mediated processes that are important in nutrient transformations and availability. Fayez (2004) reported that increasing rates of N fertilizer from 0, 150 to 300 kg N $ha^{-1}$ as urea fertilizer resulted in higher C decomposition and microbial biomass C levels in the soil. It was concluded that due to positive effects on microbial activity, N fertilization will increase nutrient cycling and, subsequently, crop productivity will improve in N-poor soils (Fayez, 2004). The main factors that control the organic matter transformation process are: the quantity and quality of litter material components, the physical and chemical environment, and the decomposition organisms (Rigobelo and Nahas, 2004).

There was significant interaction between N application rate and planting season for grain yield. Maize yield response to N was significantly better in long than in short rain seasons. This applied to all N levels, irrespective of source with exception of the control and mucuna rate of 30 kg N $ha^{-1}$ (Table 2). This was attributed to variations in seasonal rainfall. Shortage of water reduces the uptake of nutrients by a crop (Shaxson and Barber, 2003). This is largely because nutrients can only move to roots through water films within the soil, and so there must be continuous water film connecting the nutrients with the roots. A lack of soil water continuity, due to drought for example, will severely reduce the rate of nutrient uptake by crops. Also, diminish nutrient availability by reducing microbial activity, which is responsible for the liberation of N, phosphorus and sulphur from soil organic matter (Shaxson and Barber, 2003), and this limits maize yield.

## Conclusions

Legume biomass productivity and N accumulated in agro-ecological zone and niche has significant bearing on its prospect to increase soil fertility and maize grain yield.

Mucuna green manure application rate of 30 kg N $ha^{-1}$ did not have notable effect on maize grain yield. Its application at rate of 60 kg N $ha^{-1}$ increased maize yield but fell short of giving consistent significant improvement over all seasons. Mucuna application rate of 120 kg N $ha^{-1}$ equivalent to 6 t DM $ha^{-1}$ of the green manure made consistent substantial change in maize grain yield. Therefore, application of green manure at rate less than 120 kg N $ha^{-1}$ could require supplementation of the N with inorganic fertilizer applied in combination, if maximum maize grain yield is to be expected.

At application rates of 30, 60 and 120 kg N $ha^{-1}$ there is no difference in using either mucuna green manure or inorganic fertilizer, as N source in maize grain yield. Inorganic fertilizer rate of 30 kg N $ha^{-1}$ failed to give consistent significant increase in maize yield, unlike its application at 60 kg N $ha^{-1}$. There was no further consistent increase in yield, for application of excess inorganic N at rate of 120 kg N $ha^{-1}$ as this is past the optimum biological inorganic N rate of 107 kg $Nha^{-1}$.

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