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Effect of Manure and Fertilizer Application on Yield of *Sorghum almum* Harvested at Different Maturity Stages

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Abstract: This study was conducted in Naivasha, Kenya over a period of 15 weeks to determine the effect of manure and fertilizer application on yield of Columbus grass (*Sorghum almum*). After field preparation, 60 plots of 2×2 m^2 size were demarcated and further divided into 5 similar units comprising of 4 blocks of 3 plots each (N = 12). The plots in each block were independently allotted to 3 treatments in a Randomized Complete Block (RCB) design. Treatments were T_1-control (with nether manure nor fertilizer), T_2 and T_3 received manure and inorganic fertilizer, respectively. All the 4 blocks (weed free) in each of the five (randomly distributed) units were planted on the same day and harvesting at 6, 8, 10, 12 and 14 weeks in a sequential manner starting with unit 1-5. All the blocks in each unit were harvested on the same day (at 5 cm height) and the entire freshly harvested materials, per plot, were weighed. Representative grab samples were collected, chopped to pieces of 2 cm length, mixed and 2 composite samples (500 g each) were taken for Dry Matter (DM) determination and chemical analyses. DM, Ash and Crude Protein (CP) were determined according the standard procedures. Fresh Matter Yield (FMY), DM Yield (DMY), Organic Matter Yield (OMY) and Crude Protein Yield (CPY) per 4m^2 were determined and translated to equivalent ha. Collected data was stored in MS-Excel and analyzed using SAS. Results showed that, at the age of 6 weeks, FMY and DMY (ton ha^{-1}) in T_3 (8.8 and 1.2, respectively) were 66.1 and 71.4% higher ($p<0.0001$) than T_1 (5.3 and 0.7). It was also observed that, T_2 (6.9 and 0.9) and T_1 were also different ($p<0.05$) at this age. At the age of 14 weeks T_1, T_2 and T_3 recorded 62.5, 77.2 and 85.6 ton FMY ha^{-1} and 13.5, 17.1 and 19.9 ton DMY ha^{-1}, respectively. A similar trend was observed with OMY and CPY, with T_2 and T_3 (13.9 and 16.1 ton DM ha^{-1}, respectively) registering 27.5 and 47.7% higher OMY than T_1. The results also showed strong correlation of yield parameters studied. Analysis of Variance (ANOVA) showed that, treatment had strong effect on yield. It was therefore, concluded that manure or fertilizer application substantially increased the yield of *Sorghum almum*, with animal manure being the most ideal cost effective option for smallholder resource-poor farmers in Kenya.

Key words: Columbus grass, manure, inorganic fertilizer, dry matter, organic matter, crude protein

INTRODUCTION

Forages of Sorghum family are widely recognized as important feed resource for ruminants (Mohammad *et al*., 1994). Mohammad (1993) reported that *Sorghum almum* has valuable characteristics for use in sown fodder production on smallholder farms. It is a high yielder of palatable herbage, suitable for grazing, silage and haymaking (Duke, 1983). Gohl (1981) reported *Sorghum almum*'s biomass yield of 13 metric ton ha^{-1} and a stand persistence of 5-6 years. Kallah *et al*. (1999) also reported a yield of 8.7 ton ha^{-1} fresh at 7 weeks after planting and 31.5 ton ha^{-1} fresh (equivalent of 14.3 tons DM ha^{-1}) at the hard dough stage. Chemical composition of *Sorghum almum* fodder has also been studied. Gohl (1981) reported DM content of 16 and 23.9% and Crude Protein (CP) of 11.7 and 7.8%, at the age of 4 and 8 weeks, respectively. Less is however known of the forage potential of *Sorghum almum* as ruminant feed on different agro-ecological zones in Kenya. Of critical importance is the lack of information on its yields and nutritive value, as influence by maturity and soil fertility. This consequently impacted negatively on the cultivation of *Sorghum almum* on smallholder farms. The current study was conducted to investigate the effect of soil fertilization on yield of *Sorghum almum*, on the premise

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that generation of this information will enhance its production and utilization on smallholder resource-poor farms in Kenya, where ruminants' feed inadequacy is a major challenge.

MATERIALS AND METHODS

This study was conducted at the National Animal Husbandry Research Centre in Naivasha, Kenya over a period of 15 weeks. The objective was to determine the effect of soil fertilization using either manure or fertilizer on yield of Columbus grass (*Sorghum almum*). After land preparation, 60 plots (labeled 1-60) of 2×2 m^2 size were demarcated and further divided into 5 similar units (N = 12) comprising of 4 blocks of 3 plots each. The 3 plots in each block were independently allotted to 3 treatments in Randomized Complete Block (RCB) design throughout all units.

The treatments were: T_1-control (without fertilization), T_2 and T_3 received manure (2 kg of 5 day old dry cattle manure [93.17% DM, 1.711% N, 1.32% Ca and 1.12% P]) and inorganic fertilizer (50 g Di-ammonium phosphate [DAP-18: 46: 0]), respectively. Manure was applied by mixing it thoroughly with the soil (top 20-30 cm thick layer) and fertilizer was drilled with the seed. During planting, 5 rows of 2 m length, 30 cm apart and 5 cm deep were drilled on each plot and a total of 25 g of seed were sown with each row receiving exactly 5 g of seed (evenly distributed). All the plots in the five units (N = 60) were planted on the same day and kept weed free throughout the trial. Within each unit, guard rows of 30 and 60 cm between plots and blocks, respectively, were provided and also kept weed free. Harvesting was done at 6, 8, 10, 12 and 14 weeks in a sequential manner beginning with unit 1 to 5. All the plots in each unit were harvested on the same day at 5 cm height. During each harvest, all the freshly harvested materials, per plot, were weighed using field-weighing scale (50 kg). At the same time, representative grab samples of freshly harvested forage were made, chopped to pieces of 2 cm length, mixed thoroughly and 2 composite samples (500 g each) were taken for Dry Matter (DM) determination and chemical analyses.

DM was determined by oven drying at 105°C for 24 h (AOAC, 1990). Ash content was determined by ashing in a muffle furnace at 550°C (AOAC, 1990). Crude Protein (CP) was determined through the kjeldahl method (% N×6.25). Hectare Fresh Matter Yield (FMY) DM Yield (DMY) Organic Matter Yield (OMY) and Crude Protein Yield (CPY) were also determined.

Collected data was stored in MS-Excel and analyzed using SAS (2002). Analysis of variance to determine effect of treatment on study parameters (FMY, DMY, OMY and CPY) was done according to a randomized complete block design with 3 treatments and 4 replicates. The statistical model was $Y_{ij} = \mu + C_i + T_j + C_i * T_j + e_{ij}$; where Y_{ij} = FMY (kg 4 m^{-2} translated to ton ha^{-1}), DMY, OMY and CPY (ton DM ha^{-1}), μ = overall mean, C_i = age at harvest in weeks (i = 6, 8, 10, 12, 14), T_j = treatment (j = 1, 2, 3), $C_i * T_j$ = age-treatment interaction and e_{ij} = the standard error. Parameter means were compared using General Linear Model (GLM) procedure of SAS (2002).

RESULTS

Results generally showed that application of either manure or fertilizer influenced yield of the grass (Table 1). Analysis of Variance (ANOVA) showed that soil fertilization had significant effect on FMY ($r^2 = 0.7986$; $p<0.001$) and DMY ($r^2 = 0.7917$; $p<0.001$) at 6 weeks. Similar trend was noted throughout the 4 subsequent harvests. At 14 weeks, mean FMY for T_2 (77.19 ton ha^{-1}) and T_3 (85.63 ton ha^{-1}) were 23.9 ($p<0.05$, $r^2 = 0.6259$) and 37.45% ($p<0.01$, $r^2 = 0.7584$) higher than that of T_1 (62.31 ton ha^{-1}). The mean FMY (ton ha^{-1}) for T_2 and T_3 were however not different ($p>0.05$, $r^2 = 0.2875$) at this stage. The observed FMY and DMY increases between 6 and 14 weeks in T_1, T_2 and T_3, represented a daily accumulation rates of 1017.9, 1255.3 and

Table 1: Effect of manure or fertilizer application on yield (ton ha^{-1}) of *Sorghum almum* harvested at different maturity stages

	Estimated mean yield (ton ha^{-1})				
AAH	T_1	T_2	T_3	SEM	CV
Fresh matter yield					
6	5.3^a	6.9^b	8.8^c	0.4146	7.38
8	17.9^a	21.3^b	22.5^b	0.4502	4.54
10	47.7^a	57.8^b	65.8^b	0.8695	6.93
12	56.6^a	69.8^b	78.4^b	2.6922	8.67
14	62.3^a	77.2^b	85.6^b	3.6587	9.94
Dry matter yield					
6	0.7^a	0.9^b	1.2^c	0.0704	8.51
8	2.5^a	3.1^b	3.3^b	0.1271	9.64
10	7.1^a	8.8^b	10.2^b	0.4386	8.66
12	9.9^a	12.2^{ab}	14.7^b	0.9799	19.72
14	13.5^a	17.1^b	19.9^b	1.1508	16.71
Organic mater yield					
6	0.5^a	0.7^b	0.9^c	0.0525	8.84
8	1.9^a	2.3^b	2.6^b	0.0946	8.91
10	5.5^a	7.6^b	8.1^b	0.3434	8.6
12	7.9^a	9.8^{ab}	11.8^b	0.7896	19.92
14	10.9^a	13.9^b	16.1^b	0.9308	16.95
Crude protein yield					
6	0.11^a	0.16^b	0.21^c	0.0135	9.7
8	0.32^a	0.35^a	0.41^b	0.0187	6.61
10	0.67^a	0.98^b	1.06^b	0.0582	9.46
12	0.68^a	0.99^b	1.19^b	0.0701	22.09
14	0.96^a	1.19^b	1.39^b	0.0742	17.53

Means within the same row with the same super script (^{a}, ^{b}, ^{c}) are not significantly different ($p>0.05$); C.V-Coefficient of Variation; AAH-Age At Harvest (weeks)

Table 2: Regression equations fitted to describe yield pattern of *Sorghum almum* as influence by treatments and age at harvest

	Linear	N	R^2	P	Quadratic	R^2	P
FMY (kg 4 m^{-2})							
T_1	FMY = 3.06X-15.4	20	0.932	**	FMY = 8.01X-0.25X^2-38.2	0.966	***
T_2	FMY = 3.99X-19.9	20	0.911	***	FMY = 10.42X-0.32X^2-49.6	0.944	*
T_3	FMY = 4.19X-20.9	20	0.925	*	FMY = 10.45X-0.31X^2-49.9	0.954	*
FMY (ton ha^{-1})							
T_1	FMY = 7.64X-38.4	20	0.932	*	FMY = 20.04X-0.62X^2-95.5	0.966	*
T_2	FMY = 9.97X-49.9	20	0.911	***	FMY = 25.99X-0.81X^2-123	0.944	***
T_3	FMY = 10.49X-52.6	20	0.924	*	FMY = 26.09X-0.78X^2-124	0.947	*
DMY (ton DM ha^{-1})							
T_1	DMY = 1.66X-9.8	20	0.989	**	DMY = 1.02X + 0.032X^2-6.9	0.991	**
T_2	DMY = 2.26X-13.3	20	0.964	***	DMY = 1.33X + 0.046X^2-9.1	0.967	***
T_3	DMY = 2.44X-14.5	20	0.982	**	DMY = 1.08X + 0.068X^2-8.3	0.987	*
OMY (ton DM ha^{-1})							
T_1	OMY = 1.34X-8.0	20	0.989	**	OMY = 0.68X + 0.033X^2-4.9	0.991	**
T_2	OMY = 1.83X-10.9	20	0.966	***	OMY = 0.87X + 0.098X^2-6.5	0.969	***
T_3	OMY = 1.98X-11.9	20	0.982	**	OMY = 0.67X + 0.065X^2-5.9	0.988	*
CPY (ton DM ha^{-1})							
T_1	CPY = 0.104X-0.5	20	0.951	*	CPY = 0.18X-0.004X^2-0.9	0.959	*
T_2	CPY = 0.146X-0.7	20	0.897	***	CPY = 0.34X-0.01X^2-1.6	0.920	***
T_3	CPY = 0.157X-0.7	20	0.935	*	CPY = 0.34X-0.01X^2-1.6	0.953	**

FMY-Fresh Matter Yield; DMY-Dry Matter Yield; OMY-Organic Matter Yield; CPY-Crude Protein Yield; X-Age at harvest (weeks), N-Number of data entries; * $p<0.05$; ** $p<0.01$; *** $p<0.001$

1371.4 kg FMY ha^{-1} d^{-1} and 228.6, 289.3 and 333.9 kg DMY ha^{-1} d^{-1}, respectively. Contrasts between the mean DMY of the 3 treatments (Table 1) showed that at 14 weeks, T_2 (17.1 ton DM ha^{-1}) and T_3 (19.9 ton DM ha^{-1}) were 26.7 and 47.4% higher than that of T_1 (13.5 ton DM ha^{-1}).

Results however, showed that the mean DMY for T_2 and T_3 at 14 weeks were however, not different ($p>0.05$, $r^2 = 0.0437$). Mean OMY of T_1, T_2 and T_3 at 14 weeks were 10.9, 13.9 and 16.1 ton DM ha^{-1}, respectively with T_2 and T_3 recording 27.52 ($p<0.01$, $r^2 = 0.7611$) and 47.71% ($p<0.01$, $r^2 = 0.8103$) higher than T_1. The OMY means for T_2 and T_3 were however, not different ($p>0.0.05$, $r^2 = 0.0602$). OMY daily increase in T_1, T_2 and T_3 were 185.7, 235.7 and 271.4 kg DM ha^{-1} d^{-1}, respectively.

Comparison of CPY between treatments showed that, the mean for T_2 (1.19 ton DM ha^{-1}) and T_3 (1.39 ton DM ha^{-1}) were 23.96 and 44.8% higher ($p>0.05$, $r^2 = 0.0781$ and $p<0.01$, $r^2 = 0.7286$, respectively) than T_1 (0.96 ton DM ha^{-1}). Invariably, the mean CPY for T_2 and T_3 were not significantly different ($p>0.05$, $r^2 = 0.1849$). The rates of CPY gain in T_1, T_2 and T_3 were 15.2, 18.4 and 21.1 kg ha^{-1} d^{-1}, respectively. Regression functions were also fitted to describe yield trends (Table 2) with quadratic equations showing higher degree of accuracy in explaining more variation than linear model.

DISCUSSION

Results clearly showed that application of either manure or fertilizer significantly boosted the overall yield of Columbus grass (*Sorghum almum*). This was evidenced by the observed distinct differences between treatments. These differences were a reflection of a significant increase in soil total nutrients after treatment. At the age of 6 weeks, however, T_1 and T_2 were not strongly different ($p<0.05$) suggesting that the response of the grass to manure application was slower at the beginning compared to inorganic fertilizer. This was probably because manure nutrients, especially N were not released rapidly as is the case for fertilizer. Over time, however, the differences in terms of yield between T_1 and T_2 became clear with T_2 attaining much higher peak yield than T_1 at the final harvest (14th week). On the other hand, FMY and DMY in T_3 were significantly higher than T_1 ($p<0.0001$) and T_2 ($p<0.05$) at the 6th week. This difference, however, narrowed between T_3 and T_2 suggesting a continuous and sustained release of N and mineral elements in T_2 against gradual decline in soil N in T_3. This concurred with the findings of Ikombo (1983) and Probert *et al.* (1995). Snijders (1995) when investigating the effect of slurry manure on the yield of Napier grass (*Pennistum purpureum* var Bana) noted that the response of the grass on manure application was sluggish at the early stages, but its desirable effects persisted for much longer than nitrogenous fertilizer. Ikombo (1983) further reported that, in addition to increasing soil N, manure also improves essential mineral content (P and K), organic carbon, soil structure, water-holding capacity and soil aeration. The FMY and DMY for T_2 and T_3 at six weeks were comparable to those reported by Kallah *et al.* (1999) in Nigeria under 100 kg ha^{-1} N. These findings were also in agreement with those of Reeds (1976) who reported 13 ton DM ha^{-1} of 9 week old *Sorghum almum*. At the age of 90 days (about 13 weeks), Kallah *et al.* (1999) reported a DM yield of between 14.31-15.66 ton ha^{-1} of

Sorghum almum. Muia *et al*. (2000) reported DMY of between 13.7-28.5 ton ha^{-1} of Napier grass (*Pennisetum purpureum* var Bana), which is popular forage in Kenya, under 125 kg ha^{-1} N. These reports supported the results of the current study.

CONCLUSION

Results demonstrated that application of manure and fertilizer improved yield of *Sorghum almum*. Results further showed that the effect of manure and inorganic fertilizer as source of nutrients are comparable. It was therefore, concluded that soil fertilization could be used as a strategy to enhance biomass yield of *Sorghum almum*. However, owing to its low gate prices in many parts of Kenya, use of animal manure could be a cheaper option for smallholder farm situation where purchase of commercial nitrogenous fertilizers is severely constraint by farmers' low economic status.

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