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Residual Effects of Farmyard Manure on Stover and Grain Yield of Cold Tolerant Dual Purpose Sorghum (*Sorghum bicolor* L. Moench) in the Dry Highlands of Kenya

[1]G.B. Ashiono, [2]W. Wasike, [3]J.P. Ouma, [1]S.W. Gatwiku and [1]P.N. Gachuki
[1]Kenya Agricultural Research Institute-Lanet, P.O. Box 3840 Nakuru, 20100, Kenya
[2]Kenya Agricultural Research Institute, P.O. Box 57811 Nairobi, Kenya
[3]Department of Agronomy, Egerton University, P.O. Box 536 Njoro, 20115, Kenya

Abstract: An experiment was conducted over three years to determine the residual effects of different rates of farmyard manure on growth and yield of cold tolerant sorghum variety E1291. The trial was conducted on a sandy loam soil at the KARI-Lanet Research Centre. The manure levels were: 0, 5, 10, 15, 20, 30, 40 Mg ha^{-1} and inorganic fertilizer at the rate of 60 kg N and 30 kg P_2O_5 ha^{-1} applied in the first year. Grain yield increased up to 20 Mg ha^{-1} farmyard manure beyond which a decline was observed whereas, stover yield increased up to 30 Mg ha^{-1}. Residual farmyard manure consistently produced better yields than inorganic fertilizer. Grain yield increases over inorganic fertilizer ranged from 7.2 to 12.6% and those for stover were 2.3 to 8.4%. Plant population increased by 0.8 to 11.3% and harvestable heads increased from 2.6 to 20%. These results have demonstrated that high and consistent yields may be produced from residual farmyard manure for three consecutive seasons after the initial application.

Key words: Fertilizers, *Poaceae*, growth, yield, *Sorghum bicolor*

INTRODUCTION

Sorghum (*Sorghum bicolor* L. Moench) is an important staple food crop in the semi-arid tropics of Africa, South Asia and Central America. In Kenya, sorghum is ranked third after maize[1] and is adapted to drought prone environments receiving 400 mm rainfall or more. Along with other millets, sorghum has the highest production potential[2] in Kenya where 75% of the land area receives between 300-760 mm of rainfall per annum. Most of these areas are regarded as semi arid or arid zones and are characterized by low and unreliable rainfall. Sorghum can be grown successfully on a wide range of soils and can tolerate a pH range from 5.5 to 8.5 and some degree of salinity, alkalinity and poor drainage. The crop which has the potential average yield of 14 to 18 Mg ha^{-1} of forage and more than 6 to 8 Mg ha^{-1} of grain[3] can be an important food and fodder crop for the dry parts of the country. Sorghum after a period of moisture stress recommences photosynthesis immediately unlike other cereals, which may regain turgidity when water is restored but does not recover their normal photosynthetic behaviour[4]. The development of better adapted and higher yielding cultivars have increased the yield potential of sorghum. Whilst soils where sorghum is grown have moderate to high nutrient levels in their virgin state, most have suffered nutrient depletion through time, such that in many areas high yields may only be maintained by applying fertilizers. However, the increased use of acidifying nitrogen fertilizers for agricultural production has significantly contributed to the lowering of the soil pH. Farm Yard manure has the potential to improve such soils and has been used to supplement inorganic fertilizers on many farms[5].

Farmyard manure (FYM) is an important organic resource for agricultural production in crop-livestock-based farming systems in the semi-arid tropics of Kenya. Manure represents a valuable source of phosphorous (P) released following breakdown by micro-organisms in the soil that can sustain crop requirements. Farms with a total stocking rate of 1.1 tons live weight ha^{-1}, had high manure potential that contained enough P balance for crop-needs that could exclude the use of inorganic Phosphoric fertilizers[6]. However, manure is a highly variable product that is often difficult to apply accurately and releases nutrients in the soil at a rate that is highly dependent on environmental conditions.

Some anecdotal studies have shown that FYM applied alone, or in combination with Nitrogen and Phosphorous (N+P) or N+P+K fertilizer, was effective in maintaining soil quality under continuous cultivation. Oswal reported[7] that applying Farmyard manure

Corresponding Author: Dr. Josephine P. Ouma, Department of Agronomy, Egerton University, P.O. Box 536 Njoro, 20115, Kenya Fax: +254-051-62145

increased Electrical Conductivity (EC), Cation Exchange Capacity (CEC), organic carbon and soil moisture content. Similar results where FYM was found to increase water storage, soil nutrient availability and crop yield have been reported[8,9]. However information on the residual effect of farmyard manure on cold tolerant sorghum yield components is not widely reported. Local research is therefore required to establish the residual interactions of FYM with sorghum in the dry highlands. The purpose of this study conducted over three seasons was to determine the residual capacity of farmyard manure to produce reasonable grain and forage yield of cold tolerant dual-purpose sorghum.

MATERIALS AND METHODS

The trial was conducted at the Beef Research Centre Lanet which is situated 0°, 30′S, 36°E and 1920 m.a.s.l. The site represents the special climatic conditions of the Kenyan highlands where solar radiation and photoperiod is tropical and temperatures are temperate, while rainfall varies from semi-arid to medium wet. The annual rainfall at this site is 800 mm and is unreliable and poorly distributed. The area has two rainfall seasons per year. The long rain season begins in March and ends in August while the short rains begin in October and end in December. The soil is a deep sandy loam, with good water holding capacity and is classified for marginal agricultural potential in ecological zones III and IV[10]. Cold tolerant dual-purpose sorghum variety E1291 that mature in 160 days was used for this study over three seasons. Land was prepared to a fine tilth and sorghum was sown at the onset of long rains at a spacing of 60×20 cm in plots measuring 4×1.4 m. The experiment consisted of eight treatments in a Randomized Complete Block Design with four replicates. The treatments were 0, 5, 10, 15, 20, 30 and 40 Mg ha^{-1} of FYM, 60 kg of N and 30 kg $P_2O_5^{-1}$. The residual effect of Farmyard manure was evaluated for the third year running after the main experiment was concluded. Agronomic practices including weeding and pest control were followed and grain was harvested at maturity when the moisture content was 12%. Harvesting for grain involved cutting the sorghum panicles with a knife from one of the middle rows. The heads were subsequently threshed and the grain weighed. Total dry matter was determined at harvesting by hand cutting plants at ground level from the other middle row and chopping them into small pieces. The plant samples were oven dried at 50°C for 48 h and the dry matter recorded. Analysis of variance was conducted on data using GENSTAT[11]. Fishers protected Least Significant Difference (LSD) at the 5% level of probability was used to separate treatment means.

RESULTS AND DISCUSSION

There were no significant differences observed among residual rates of FYM on grain and stover yields. However, grain yield increased up to 20 Mg ha^{-1} FYM (Table 1) beyond which a decline was observed whereas stover yield increased up to 30 Mg ha^{-1} (Table 1). Increases in grain yield ranged from 7.2 to 12.64% over the recommended inorganic fertilizer rates (Table 2). The residual 20 Mg ha^{-1} FYM produced the highest (12.64%) grain yield over the recommended inorganic fertilizer (60 kg N and 30 kg P_2O_5) that also produced the lowest yields. Increases in stover yield due to the residual effect of FYM ranged from 2.3 to 8.4% over the recommended inorganic fertilizer rates. Significant differences ($p<0.013$) were observed in plant population with increases ranging from 0.8 to 11.32% (Table 2). The residual rates of 15 Mg ha^{-1} (10.44%) and 20 Mg ha^{-1} produced the highest while the lowest plant populations were observed where no fertilizers or manure (0 Mg ha^{-1}) had been applied (Table 2). There were no significant treatment differences observed in the number of harvested heads although slightly more heads were harvested in residual 20 and 30 Mg ha^{-1} FYM while lowest number of heads was obtained with the inorganic fertilizers.

A general trend was observed where sorghum grain and stover yields increases with the residual FYM compared to the inorganic fertilizer application. A similar trend was also observed in plant population clearly indicating the long-term efficacy of FYM in maintaining soil quality[12]. The applied farmyard manure may have influenced nutrient availability for sorghum growth probably by helping to bind soil particles into stable aggregates thereby influencing the activities of soil

Table 1: Sorghum grain and stover yield response to residual farm yard manure for three seasons at Beef Research Centre, Lanet, Kenya

	FYM rates (Mg ha^{-1})							
	0	5	10	15	20	30	40	60
Grain yield (Mg ha^{-1})	5.14	5.65	4.77	5.83	5.88	5.88	5.34	5.26
Stover yield (Mg ha^{-1})	18.98	18.98	20.37	20.83	21.30	19.91	19.91	19.91

Table 2: Percentage response of cold tolerant sorghum to residual FYM over inorganic fertilizer after three cropping seasons

Manure and fertilizer	Grain yield increase (%)	Stover increase (%)	Harvestable heads (%)	Increase in plant population (%)
60 kg N+30 kg P_2O_5	0.00	0.00	0.00	0.00
5 Mg ha^{-1}FYM	7.20	4.60	2.60	0.00
10 Mg ha^{-1} FYM	9.35	2.30	5.40	0.80
15 Mg ha^{-1} FYM	11.82	4.76	9.20	10.44
20 Mg ha^{-1} FYM	12.64	4.70	16.00	11.32
30 Mg ha^{-1} FYM	11.76	8.40	20.00	0.00
40 Mg ha^{-1} FYM	2.30	0.00	5.40	2.61

Footnote: FYM farm yard manure

organisms resulting in increased soil microbial biomass Carbon © and Nitrogen (N). A strong link has been shown to exist between earthworm populations in farming systems where organic manure was retained[13]. Such soils with improved structural capacities (good stability or lower strength) were found to increase the uptake of nutrients due to better root growth.

Although Increases in soil Nitrogen (N) and organic Carbon © concentrations are linked to the quantity of manure in the soil[14], the reduction in yields at higher rates (40 Mg ha^{-1}) of residual FYM may have been due to the reduced rates of biomass turnover. High concentrations of farmyard manure are likely to have decomposed slowly retarding the availability of nutrients. The slow process however, is beneficial because more populations of soil micro-organisms are supported for a longer time, which is also necessary for the long-term maintenance of the soil structure and fertility levels required for intensive crop production.

Grain and stover yields, plant population and the number of harvestable heads were consistently lower with the inorganic fertilizer. This may have been due fast depletion by sorghum of applied nutrients that were in a readily available form. Additionally, the ability of the soil to supply nutrients for crop growth is linked to the pH and is used as a benchmark for amelioration measures. There is a possibility that the nitrate that was originally applied in the form of an ammonium-based fertilizer was lost through leaching and product removal through grain and stover over the years contributing to acidification. Such changes in the soil physical and chemical properties may have affected the availability and uptake of nutrients leading to low yields.

Higher levels of residual FYM produced highest sorghum stover and harvestable heads compared to grain yield, which exemplifies the appropriateness of E1291 as a dual-purpose sorghum variety. Higher number of heads did not necessarily result in higher grain yield probably due to lower seed weight and bird damage.

CONCLUSIONS

This study has shown that production of cold tolerant sorghum can be sustained by using residual farmyard manure. High grain and forage yields were achieved due to the residual effect of FYM indicating the benefits bestowed on the soil due to manure application while the application of high inorganic fertilizer to cold tolerant sorghum is wasteful and inappropriate. The study has also shown that cold tolerant sorghum responds well to residual FYM up to 30 Mg ha^{-1} for grain and forage production and 15 Mg ha^{-1} for grain only for three consecutive cropping seasons. Residual Farmyard manure levels of 15 Mg ha^{-1} can be recommended for grain production of cold tolerant dual-purpose sorghum and 30 Mg ha^{-1} for forage production. The higher-level FYM can also be recommended for both grain and forage production if the cost and availability of manure can allow it. Residual rates beyond 40 Mg ha^{-1} of farmyard manure should be evaluated. Use of FYM seems to be a viable option for resource poor farmers who cannot afford costly inorganic fertilizers, particularly for sorghum production.

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