Journal of Agricultural Science; Vol. 5, No. 5; 2013
ISSN 1916-9752 E-ISSN 1916-9760
Published by Canadian Center of Science and Education

Effects of Cow Dung Treated to Various Management Practices and Nitrogen Levels on Maize Grain Yield in the Northern Guinea Savanna of Nigeria

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Received: December 3, 2012 Accepted: February 28, 2013 Online Published: April 15, 2013

doi:10.5539/jas.v5n5p226 URL: http://dx.doi.org/10.5539/jas.v5n5p226

Abstract

This study consisted of collection and incubation of cow dung, followed by evaluation of the incubated cow dung in field experiments in years 2003 to 2004 at the Institute of Agricultural Research, Ahmadu Bello University and Samaru College of Agriculture farms, all located in Samaru, Zaria. The objectives of this study are to determine the effects of subjecting cow dung to different management practices and nitrogen fertilizer on maize grain yield. The study was a factorial experiment, with 3 cow dung management practices, 4 storage durations in the field and 2 levels of nitrogen. There was a control treatment, where no cow dung or nitrogen fertilizer was applied. These gave a total of 25 treatment combinations, laid out in a randomized complete block design, replicated three times. The results showed that, the best cow dung management practice that gave the highest maize grain yields in the two farms was the surface heaped covered in April, nitrogen amended treatment. The non N amended treatments were not able to significantly increase the maize grain yields than the untreated control.

Keywords: cow dung, management practices, urea fertilizer, maize, yield, northern guinea savanna and Nigeria

1. Introduction

Maize is the third most important cereal crop in the world after rice and wheat (Food Agricultural Organization [FAO], 1997), and the second most important cereal crop in the farming systems of the Guinea savanna of Nigeria (Tarfa et al., 2003). Among these three crops, maize have been found to have the highest average yield per hectare and a good source of energy for human and animal and has been discovered to be very easy to process and readily digestible (Okoruwa & Kling, 1996). In Nigeria, maize is a very important cereal crop in the farming systems of the Guinea savanna and about 4.5 million tones was produced in the country from 3.5 million hectares of land in 1983 with the Guinea savanna accounting for 70 percent of this total production (Enwenzor et al., 1989). In 1984, land area under maize cultivation in Nigeria was estimated to be about 653,000 ha and it rose to about 5.4m ha in 1994 and lately decreased to 4.5 m ha in 2004 (Federal Ministry of Agriculture [FMA], 2005). A number of factors could have been responsible for the decrease in production and productivity.

The moist savanna (Guinea savanna) region of sub-Sahara Africa (SSA) with 42% of the SSA human population has been recognized to have the potential for increased crop and livestock production (McIntire, Bourzart, & Pingali, 1992; Winrock, 1992; Jabbar, 1996). Increasing agricultural productivity in the region without due attention to natural resource management or the fragile soil resource of the region could impose negative consequences. It is estimated that as much as 85% of the land in this region is threatened by degradation (International Food Policy Research Institute [IFPRI], 1995).

The current global drive for sustainable agricultural systems that optimize use of low inputs, require close monitoring of soil quality (FAO, 1989). To achieve this, integrated soil fertility management systems, by combining the use of chemical amendment, biological and local organic resources, such as crop residues, green manure, biological N- fixation and agro-forestry for low activity clays of the savanna soil have been suggested (Kang & Wilson, 1987). The critical factor for the success of improved farming systems seem to be the efficient recycling of organic materials (Kang & Duguma, 1985).

The recent increases in cost of inorganic fertilizers, has triggered scientific interest towards the evaluation of organic fertilizers based on locally available resources, including crop residues, animal manure and green manures (Reijntjes, Haverkrot, &Waters-Bayer, 1992). Focus on soil fertility research has shifted towards the combined application of organic matter and mineral fertilizers as a way to arrest the on going soil fertility decline in sub Saharan Africa (Vanlauwe, Wendt, & Diels, 2001c). The organic sources can reduce the dependency on costly fertilizers by providing nutrients that are either prevented from being lost (recycling) or more truly added to the system (biological N-fixation). When applied repeatedly, the organic matter leads to build-up of soil organic matter, thus providing a capital of nutrients that are slowly released (Giller et al., 1997) and at the same time increasing the soils buffering capacity for water, cations and acidity (de Ridder & van Keulen, 1990).

Animal manure (called manure) according to Defoer, Budelman, Toulmin and Carter (2000) is an organic fertilizer consisting of partly decomposed mixture of dung and urine. Manure is recognized as a key resource in sustaining soil fertility in the tropics, supplying the soil with a range of macro- and micro- nutrients and organic matter. According to Camberato, Lippert, Chastain, and Plank (1996) and Fulhage (2000) the nutrients content of manure varies widely with animal species, age, ration quality and feed consumption, as well as with different methods of storage, handling methods, housing type, temperature and moisture content, treatment and land application. The beneficial role of animal manure in crop production has long been recognized (Schlecht, Mahler, Sangare, Susenbth, & Becker, 1995; Karanja, Kapkiyai, Bunyasi, & Murage, 1997; Harris, Lyord, Hofni-Collins, Barrett, & Brown, 1997). The utilization of cattle manure as a soil amendment is an integral part of the Nigerian guinea savanna farmers (Harris & Yusuf, 2001; Iwuafor et al., 2002). However, the information that is lacking to most of the farmers is the methods of manure management practices for optimal quality before field application and time of application of animal manure for optimum crop production. Also, Iwuafor et al. (2002) observed that, the results of trials conducted in the northern guinea savanna showed the need to investigate the high variability in manure quality across different farmers/sites, and to look for ways to avoid losses during manure storage, or at least to establish ranges of N contents for manures with different origins and storage methods. Therefore, the objectives of this study are to determine the effects of cow dung subjected to different management practices and Urea fertilizer on maize grain yield in the Northern Guinea Savanna of Nigeria.

2. Materials and Methods

2.1 Location and Description of Experimental Site

The field studies were carried out at Samaru at two different locations within the same zone at the IAR Research Farms and the Samaru College of Agriculture (SCA) Farm, Samaru, which are both located at Latitude 11° 11′ N and Longitude 7° 33′ E in the Northern Guinea Savanna zone of Nigeria.

Samaru has mean annual rainfall of about 1050 mm, spanning the periods from May to September, while the dry season starts from October to April with a mean daily temperature of 24°C (Kowal & Knabe, 1972). The hottest months are those that precede the rains (March to April) and coldest months occur in November to January, October and February are considered as transition months. The global radiation is evenly distributed throughout the year, ranging from 440 cal. cm^2 day^{-1} in August to 550 cal. cm^2 day^{-1} in April to May (Kowal, 1972).

2.2 Cow Dung Collection and Subjected to Management Practices

The study consisted of collection and incubation of cow dung and subsequent evaluation using field experiments. The cow dung that was used for these experiments were collected from the National Animal Production Research Institute (NAPRI), Shika-Zaria in years 2003 and 2004. The cow dung collected was subjected to different management practices as described in Figure 1.

Fresh cow dung was collected early in the morning from pens and piled into a heap. The cow dung was then mixed thoroughly with a shovel with the aim of harmonizing it. After mixing it thoroughly, it was then subjected to the various management schedules as follows: (i) cow dung placed in a pit of 2 x 2 m and 75 cm deep and covered (PC) with a polythene sheet, (ii) cow dung heaped on the ground surface and covered (SHC) with a polythene sheet, and (iii) cow dung heaped on the ground surface and left uncovered (SHU). The collection of the cow dung and its distribution to the 3 different management practices was repeated for the next 2-3 days as described above until enough cow dung was gathered. The cow dung was then allowed to decompose for four weeks (one month, composting) without any disturbance before it was removed and stored in the field.

This experiment started in February, 2003 with the collection of cow dung and allowing it to decompose (composting) for 4 weeks which means the field storage (exposure) of the cow dung was from March to May (12 weeks of field storage before application to the soil as amendment). The same cow dung treatment as described for February above was repeated in March against April to May (8 weeks of field storage before application to the soil as amendment), April against May (4 weeks of field storage before application to the soil as amendment) and May against June (0 week) where cow dung was collected at the termination of composting and applied to the field immediately, without field storage (the moisture content was taken into consideration). The same procedure was repeated in the second year (2004).

Weeks	Treatments	1 2 3 4	5 6 7 8	9 10 11 12	13 14 15 16	17 18 19 20	Duration of Storage
Month		January	February	March	April	May	
PC	Treatment 1		Composting	Field Storage			12wks
	Treatment 2			Composting	Field Storage		8wks
	Treatment 3				Composting	Field Storage	4wks
	Treatment 4					Composting	0 wk
SHC	Treatment 1		Composting	Field Storage			12wks
	Treatment 2			Composting	Field Storage		8wks
	Treatment 3				Composting	Field Storage	4wks
	Treatment 4					Composting	0 wk
SHU	Treatment 1		Composting	Field Storage			12wks
	Treatment 2			Composting	Field Storage		8 wks
	Treatment 3				Composting	Field Storage	4 wks
	Treatment 4					Composting	0 WK

Figure 1. Diagrammatic presentation of experimental set up

2.3 Cow Dung and Soil Sampling and Preparation

Cow dung samples were taken after subjecting the cow dung to the three different management practices i.e. (PC, SHC and SHU) but before taking them to the field for storage. This set of cow dung after collection was air dried and stored for analysis. The second sampling of the cow dung was done at the end of field storage, before application and incorporation into the soil in the field (at this stage, the cow dung treatments must have been exposed at the field in storage after the 1 month of composting for different time durations of 12 weeks, 8 weeks, 4 weeks and 0 week). These were all carefully processed and kept for analysis and for use in the field.

Before the commencement of the experiment surface soil sample (0 to 20 cm depth) was collected from the field where the field experiment was conducted at IAR and SCA farms. The soil was air-dried and sieved to pass through the 2 mm sieve and kept for analysis.

2.4 Cow Dung and Soil Analysis

The surface soil samples for field studies were analyzed by the following methods: particle size distribution using the standard hydrometer method (Klute, 1986). The soil pH was determined in water and 0.01 M $CaCl_2$ with a pH glass electrode using a soil: solution ratio of 1 : 2.5. Organic Carbon was determined by wet oxidation method of Walkley-Black (Nelson & Sommers, 1982).

Exchangeable bases were determined by extraction with neutral 1 N NH_4O AC saturation method. Potassium and Sodium in the extract were determined by the flame photometer, while Ca and Mg were determined by atomic absorption spectrophotometer (Juo, 1979). Available P was extracted by the Bray 1 method. The P concentration in the extract was determined colorimetrically using the spectronic 70 spectrophotometer. Total N was determined by the Kjeldahl procedure (Bremner & Mulvaney, 1982; Bremner, 1982).

2.5 Field Experiments

The field experiments were conducted at two locations. The first trial was carried out at the IAR Farm, Samaru in the year 2003 season. The second trial was established at the SCA Farm, Samaru in 2004 season. In all the experiments, the same treatment combinations, experimental design, observations and procedures were maintained.

The experiment was a factorial experiment with 3 factors, laid out in a randomized complete block design replicated three times. The treatments were: 3 cow dung management practices, 4 different storage times after 1 month incubation (composting) before application to the field, 2 levels of N (3 x 4 x 2). There was a control treatment where no cow dung or nitrogen fertilizer was applied. These gave a total of 25 treatment combinations.

The land was plowed and harrowed and the field was mapped out into plots in the first year of the experiment. The plot sizes were 4 x 5 m (20 m^2) and each plot was separated from the other by one meter. The plots were then immediately ridged manually at 75 cm between ridges with the hand hoe to incorporate the cow dung. Cow dung subjected to different management practices which had been conveyed and stored in the field at different times (March for 12 weeks, April for 8 weeks, May for 4 weeks and June for 0 week) were applied manually at 5.0 t ha^{-1} on dry matter weight basis.

In both years of the experimentation, maize (Var. Oba super II) dressed with Fernasand D was sown at two seeds per hole, at a spacing of 25 cm within the row. The seedlings were later thinned to one plant per hill at two weeks after planting.

A blanket application of P was applied as single super phosphate (SSP) at the rate of 60 kg P_2O_5 ha^{-1} and at 45 kg N ha^{-1} as urea was applied in two split equal doses to the appropriate plots. The first application was done immediately after the first weeding (3 WAP). The second dose was applied at the time of second weeding (6 WAP). In each case the fertilizer was applied by single band about 5 cm deep, made along the ridge, 5-8 cm away from the plant stand and covered immediately.

The weeding operation was carried out at the third and sixth weeks after planting. Remolding was carried out at 8-9 WAP to ensure proper weed control and a clean field at the time of harvesting.

The net plots (four inner rows) were harvested when the crop was fully matured and dry. Ears for each net plot were de-husked and the fresh weight of the cobs was taken immediately. After sun drying, the cobs were shelled using the manual Sheller. The dry grain weight for each treatment was recorded.

2.6 Statistical Analysis

The data collected from the field studies were subjected to analysis of variance (ANOVA) using the SAS package (SAS Inst., 1999). Significant means were separated using the Duncan's Multiple Range Test (DMRT) at 5% level of probability.

3. Results and Discussion

Some selected physical and chemical properties of the two sites are shown in Table 1, while the NPK content of the cow dung used in the field experiments are presented in Table 2.

Table 1. Some physical and chemical properties of the soil of the first and second experimental sites at commencement of study

Parameters	**IAR Farm**	**SCA Farm**
Sand (g kg^{-1})	640	360
Silt (g kg^{-1})	210	540
Clay (g kg^{-1})	150	100
Texture	Sandy loam	Silt loam
pH 1:2.5 (H_2O)	5.90	5.90
pH 1:2.5 ($CaCl_2$)	5.10	5.20
Organic Carbon (g kg^{-1})	7.40	4.40
Total N (g kg^{-1})	0.53	0.70
C/N ratio	14.00	6.29
Bray 1 P (mg kg^{-1})	7.00	2.00
Exchangeable Calcium (cmol kg^{-1})	2.00	1.60
Exchangeable Magnesium (cmol kg^{-1})	0.80	1.00
Exchangeable Potassium (cmol kg^{-1})	1.84	0.49
Exchangeable Sodium (cmol kg^{-1})	1.87	1.13

IAR = Institute for Agricultural Research; SCA = Samaru College of Agriculture.

Table 2. Total NPK content of cow dung used for greenhouse and field studies

Management practices (one month incubation)	Time of manure exposure in the field before use (weeks)	2003 SEASON						2004 SEASON					
		N (%)		P (%)		K (%)		N (%)		P (%)		K (%)	
		a	b	a	b	a	b	a	b	a	b	a	b
SHUM	12	1.05	1.40	0.75	0.25	5.48	1.65	0.88	1.00	0.67	0.64	3.60	2.78
SHUA	8	1.40	1.40	0.39	0.39	1.43	1.65	1.23	1.08	0.60	0.67	3.30	3.08
SHUY	4	1.40	1.58	0.60	0.50	1.35	1.35	1.23	1.20	0.60	0.91	2.55	6.08
SHUJ	0	1.75	1.75	0.53	0.75	1.25	2.25	1.20	1.23	0.67	0.71	3.68	2.63
SHCM	12	1.23	1.40	0.75	0.67	1.35	1.75	1.05	1.08	0.39	0.51	1.73	2.10
SHCA	8	1.40	1.05	0.83	0.39	1.50	1.28	1.23	1.10	0.46	0.60	0.98	4.65
SHCY	4	1.23	1.23	0.67	0.32	1.65	1.43	1.23	1.58	0.53	0.71	1.88	3.53
SHCJ	0	2.10	1.93	0.91	0.75	1.50	3.08	1.23	1.25	0.53	0.60	0.98	2.55
PCM	12	1.75	1.45	0.79	0.39	3.15	1.98	1.05	1.05	0.80	0.60	4.88	1.58
PCA	8	1.75	1.05	0.60	0.32	5.25	1.20	1.58	1.58	0.53	0.53	4.28	1.80
PCY	4	1.58	1.75	0.67	0.49	3.68	1.58	1.98	1.05	0.53	0.71	3.15	2.63
PCJ	0	1.75	1.58	0.83	0.53	4.28	1.58	1.70	1.70	0.58	0.53	3.60	1.73
CONTROL	-	1.58		0.75		1.65		1.55		0.73		1.50	

a = At termination of 1 month incubation; b = At time of application for field trial.

SHUM = Surface heaped uncovered March
SHCM = Surface heaped covered March
PCM = Pit covered March
SHUA = Surface heaped uncovered April
SHCA = Surface heaped covered April
PCA = Pit covered April
SHUY = Surface heaped uncovered May
SHCY = Surface heaped covered May
PCY = Pit covered May
SHUJ = Surface heaped uncovered June
SHCJ = Surface heaped covered June PCJ = Pit covered June

3.1 Maize Grain Yields

The effects of cow dung management practices, duration of storage before field application and N levels on maize grain yield for 2003 and 2004 seasons are shown in Table 3. There were significant ($P < 0.05$) differences among the treatments in the two farms. Results of treatments were consistent for the two years e.g. all the N amended treatments (+N) consistently gave higher maize grain yield values than the zero N amended (oN) treatments. The values for the control also consistently gave lower values compared to the N amended treatments. Where treatments were amended with nitrogen, the surface heaped covered April treatment (SHCA) consistently gave higher maize grain yields in the two years. Among treatments that were not amended with N, the surface heaped uncovered May (SHUY) gave higher grain yields in the two years (farms).

Table 3. Effects of manure management practices, time of application and nitrogen levels on maize grain yield (kg ha^{-1}) in IAR and SCA farms

Treatments	IAR farm 2003		SCA farm 2004	
	oN	+N	oN	+N
SHU				
SHUM	1120.8c-f	1925.0a-e	241.7i	1308.3c-g
SHUA	904.2ef	2341.7ab	500.0hi	2158.3ab
SHUY	1645.8a-e	2195.8abc	800.0e-i	1633.3a-d
SHUJ	1341.7b-f	1966.7a-e	225.0i	1083.3d-h
SHC				
SHCM	959.2def	1629.2a-e	243.3i	1316.7c-g
SHCA	1270.8b-f	2545.8a	691.7f-i	2308.3a
SHCY	1312.5b-f	1987.5a-e	441.7hi	1466.7b-e
SHCJ	1395.8a-e	1875.0a-e	525.0hi	1050.0d-h
PC				
PCM	1079.2c-f	2090.8a-e	508.3hi	1950.0abc
PCA	1412.5a-e	2112.5a-e	766.7e-i	1766.7a-d
PCY	1387.5a-e	2120.8a-d	608.3ghi	1416.7c-f
PCJ	1345.8b-f	1904.2a-e	208.3i	1108.3d-h
Control	211.7f		275.1i	
SE+	348.65		230.96	

Means with the same letter(s) within the same group are not significantly different at 5% level of significance

SHUM = Surface heaped uncovered March, SHCM = Surface heaped covered March,
PCM = Pit covered March, SHUA = Surface heaped uncovered April,
SHCA = Surface heaped covered April, PCA = Pit covered April,
SHUY = Surface heaped uncovered May SHCY = Surface heaped covered May
PCY = Pit covered May SHUJ = Surface heaped uncovered June
SHCJ = Surface heaped covered June PCJ = Pit covered June
oN = Direct evaluation (non N amended), +N = 45 kg N ha^{-1} (N amended).

But looking at the nutrient content of the cow dung used in Table 2, particularly the N content; it was expected that the June treatments which had the highest N content irrespective of the management practice at the time of application of cow dung to the field to give the highest grain yield. This was not so probably because of the nature of the nutrient release pattern, which did not coincide with the period of highest nutrient demand by the maize crop to produce the optimum grain yield. The management practices must have enhanced nutrient availability with the period of highest nutrient demand by the maize crop through the incubation process which must have enhanced nutrient availability to coincide with the period of highest nutrient demand by the maize crop at the SHCA treatment that gave the highest grain yield. Many scientists have advanced reasons why such discrepancies in the manure do exist. Myers, Palm, Guevas, Gunatilleke and Brossard (1994) reported that good manure should synchronize mineral nitrogen release and plant demand such that the peak mineral nitrogen release coincides with peak plant biomass development and hence peak nitrogen requirements. Also, Lekasi, Ndung'u and Kifuko (2005) reported that it is advantageous if the organic materials added to the soil mineralize nutrients slowly and the rate of nutrient mineralization increased as the plant growth progressed. He further explained that, good soil releases adequate nutrients for optimum plant growth as they mature. Closer synchronization of nutrients demand ensures efficient utilization of organic inputs applied to the soil, he added. In other words, high content of nutrients in the cow dung was not an indication for high performance in crop production. Organic materials that mineralize too readily, subject mineralized nutrients to losses through processes such as leaching and volatilization on the other hand, organic materials that releases nutrients later in the season will not benefit the plant or crop as it would have matured with inadequate availability of nutrients during the critical growing stages. The overall amounts of nutrients released from organic amendments for crop uptake depends on the quality, the rate of application, the nutrient release pattern and the environmental conditions (Mugwira & Mukurumbira, 1986; Murwira & Kirchmann, 1993).

All the N amended treatments gave significantly ($P < 0.05$) higher grain yields than the control treatment, while most of the non N amended treatments were statistically at par with the control treatment. This showed that, the application of cow dung alone that have been subjected to different management practices, was not enough to give a significant difference on maize grain yield. This agreed with the work of Uyovbisere and Elemo (2002) who stated that organic matter cannot be used alone, but with some level of inorganic fertilizer. It has been recognized that the combined application of organic matter and inorganic fertilizer is required to increase crop production and arrest soil nutrient depletion in West Africa (FAO, 1999; Giller, 2002; Iwuafor et al., 2002). Tanimu, Iwuafor, Odunze and Tian (2007) reported higher doses of N fertilizers increased grain yield and yield related components of maize.

4. Conclusion

Based on the results of this study, the surface heaped covered April (SHCA). N amended treatment consistently gave the highest maize grain yield in the two farms than all other treatments. The non N amended treatments was not able to significantly increase the maize grain yields than the untreated control. It is therefore concluded that for high maize productivity in this zone the surface heaped covered April treatment, amended with N at 45 kg N ha^{-1} is recommended for use.

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