Effect of locally available organic manure on maize yield in Guinea, West Africa

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Abstract

Effects of two locally available organic fertilizers (bat guano and chicken manure) and conventional mineral fertilizer on yields of maize in low input agriculture were compared on two test sites in the Lower Guinea region of Guinea, West Africa. – The climatic conditions in the experimental area are characterized by one rainy season (April until October), and annual rainfall ranging from 3,000 mm to 4,000 mm, with a maximum in July and August. Soils on the two sites were classified as Plinthosol and Ferralsol on one site and as Fluvisol on the other site (FAO). On the two test sites the treatments were: 1. bat guano, 2. chicken manure, 3. mineral fertilizer, 4.bat guano plus mineral fertilizer, 5.chicken manure plus mineral fertilizer, 6.treatment without fertilizer application (control plot), with six repetitions. Results of the first experimental year show that both organic fertilizers resulted as apt or even better alternatives compared with conventional fertilizers. Currently recommended rates of mineral fertilizer application are too low according to the study results. Grain yield and biomass production of maize on plots where treatments included organic manure were raised significantly compared with the control plot.

Keywords: Guinea, West Africa, organic fertilizers, biomass production of maize

Introduction

Guinea's most important economic sector is agriculture, since the contribution of agriculture to the gross domestic product (GDP) is 24% and a big majority of the population depends on agriculture as working place and living base (Soumah, 1998; personal communication. and Hasson, 1988). Nevertheless Guinea has to import a big share of its food demand. Therefore intensification of agricultural production is one of the main aims of the Guinean government (Ministère de l'Agriculture, des Eaux et Forê ts, 1997).

Three forms of traditional intensive agricultural production systems already exist in Guinea: The "*tapades*" in Middle Guinea are areas which are fenced in and where cow manure is applied. In the mangrove zone of Lower Guinea, fluvio-marine sedimentation and careful water management allow intensive rice crop. Moreover the valley bottoms ("*bas fonds*") offer sufficient water supply for cultivation throughout the year. Apart from these traditional intensive systems fallow periods of up to seven years and longer after two or three years of cultivation are usual and necessary unless additional nutrients are supplied. Because of the high prices of conventional fertilizers the utilization of locally available sources of plant nutrients has become more important. A study was therefore designed to test two locally available organic fertilizers-bat guano and chicken manure-on representative soils of Guinea.

While chicken manure is not used on a larger scale by the local farmers, the use of bat guano is already a tradition in some areas of Guinea. A study about the agrarian systems in Lower Guinea showed that intensification implies changes in the social structures of the village communities, especially the change from common agricultural resource management to individual property (Tavan, 1993). In this context not only the agronomic effects but also the social aspects of the already practised use of bat guano in the traditional agriculture are an important issue for the development and implementation of future intensification strategies. Taking into consideration the "*local knowledge*" (Stocking, 1998) new management practices can be developed using the organic fertilizers, of which the agronomic effects on maize (*Zea mays*) yields were tested in this study, during the first year in the 1999 cropping season.

Materials and Methods

Experimental sites

Two experimental sites were selected to conduct the field experiments: The first site was chosen because of its soil with ferrallitic properties in the district of Bangouya (at 09°48′09″N, 13°17′24″W; 150 m above sea level), which is representative for a big share of Guinea's soils, which are characterised by similar ferrallitic properties. The other experimental field was set up in the district of Dabon (at 09°48′17″N, 13°19′38″ W; 138 m above sea level) in a valley bottom ("*bas fonds*") with sufficient water supply throughout the year and therefore with the potential of more intensive agriculture. Both experimental sites were situated approximately 60km from Conakry in the Lower Guinea region. On both sites land used for the experiment was formerly farmed by the local farmers but had been left fallow for more than three years prior to the 1999 cropping season. The climatic conditions in the experimental area are characterised by one rainy season (April until October), and total annual rainfall ranging from 3,000 mm to 4,000 mm, with a maximum in July and August.

On each site two soil profiles were analyzed to represent the variation of soil properties on each experimental field. According to the World Reference Base for Soil Resources (FAO, 1998) soils were classified as Plinthic Ferralsol (Bangouya1) and Petric Plinthosol (Bangouya2) in Bangouya and as Dystric Fluvisol (Dabon1) and Dystri-Epigleyic Fluvisol (Dabon2) in Dabon (Bridges, 1997).

Soil analysis

Soil samples were taken from each horizon of the profiles and from 0-20cm of each plot of the experimental fields. Soil analysis included texture, soil acidity, electric conductivity (EC), nitrogen- and carbon-content and cation exchange capacity (CEC) for the horizon-samples and soil acidity, EC and nitrogen- and carbon-content for the plot-samples. Particle-size distribution was analyzed by the sieving of soil suspension (>630µm, >200µm, >63µm-sand fraction) and pipetting from a sedimentation cylinder (<20µm, <6µm, <2µm-silt and clay fraction). pH-H_2O and pH-$CaCl_2$ were determined with soil suspension in deionised water (1:2.5) and soil suspension in 0.01 M $CaCl_2$-

solution (1:2.5) respectively. Soil suspension in deionised water (1:10) was used for the determination of EC. Soil content of nitrogen and carbon was analyzed using an element-analysator (Carlo Erba NA 1500). Without changing the pH-value of the soil suspension, CEC was determined by extraction with 0.1 M $BaCl_2$ (shaking) and measurement of cations with AAS and ICP.

Experimental design and treatments

On both sites the experiment was laid out in a randomized block design with six replications. The treatments were designated as follows:

1. Bat guano at the rate of 10 t ha^{-1}
2. Chicken manure at the rate of 10 t ha^{-1}
3. Mineral fertilizer at the rate of 150 kg 17-17-17 NPK-compound fertilizer and 50 kg urea ha^{-1}
4. Bat guano at the rate of 10 t ha^{-1} plus mineral fertilizer at the rate of 150 kg NPK and 50 kg urea ha^{-1}
5. Chicken manure at the rate of 10 t ha^{-1} plus mineral fertilizer at the rate of 150 kg NPK and 50 kg urea ha^{-1}
6. Control (no manure application)

The individual plot size was 4.0 m*5.0 m (20 m^2). Planting was done in 75 cm rows using intra-row spacing of 25 cm (six rows and 19 plants per row on each plot). Thus a plant density of 57,000 plants ha^{-1} was obtained (Amoruwa *et al.*, 1987).

Sources of organic manure

Two types of locally available organic fertilizers were tested and compared with mineral fertilizers at recommended rates: bat guano and chicken manure. Bat guano was taken from several caves near Kindia (Eastern Lower Guinea), chicken manure could be obtained from a chicken farm near Conakry.

Field operations and data collection

On the experimental fields maize variety K9101 (Agronomic Research Centre Kilissi/Lower Guinea -105 days vegetation period), which is commonly used by the local farmers, was sown with 3-4 seeds per hill at the end of May (Dabon) and at the beginning of June (Bangouya) and was thinned to one seedling per hill 20 days after sowing. At the time of sowing, 20 kg of either chicken manure or bat guano were applied on the corresponding plots (Ponsica, 1983). Mineral fertilizer was applied in two doses according to the actual recommendation -300 g $polt^{-1}$ 17-17-17 NPK-compound fertilizer together with 50 g $polt^{-1}$ urea 20 days after sowing and a second dose of 50 g $polt^{-1}$ urea 45 days after sowing. Plots were harvested at the beginning (Dabon) and in the middle of October (Bangouya). Grain yields and total production of dry biomass were measured.

Results and Discussion

Soil characteristics

Shallow root-accessible soil depth (Bangouya2, Dabon2) is an important soil criterion due to ironstone crust (*petroplinthic* horizon) in Bangouya and due to high groundwater level in Dabon. Texture is characterized by high sand (especially Dabon1) and low silt contents. Soil key-properties of both sites are low pH-values, fair C-contents, insufficient N-contents and very low CEC values (Table 1) (Fagbami and

Shogunle, 1995). Soils are acid to strongly acid with a remarkable difference between pH-H_2O and pH-$CaCl_2$ values due to the high share of H- and Al-ions among exchangeable cations. Soils of both sites do not have a satisfactory nutrient retention capacity which is expressed by extremely low CEC values. Exchangeable Al contents are high compared with exchangeable Ca (except Bangouya2), which implies the possible danger of Al-toxicity. Overall the soils of both sites show a very low fertility.

Table 1 Key properties of soils in Bangouya and Dabon.

Profile-soil depth	Sand %	Silt %	Clay %	pH-H_2O	pH-$CaCl_2$	EC-1:10 μScm^{-1}	C_t %	N_t %	Al cmol kg^{-1}	Ca cmol kg^{-1}	CEC cmol kg^{-1}
Bangouya1											
0-20cm	65.4	4.7	29.9	4.97	4.12	7.5	0.83	0.03	0.91	0.41	1.62
20-42cm	69.2	5.9	25.0	4.95	4.1	6.8	1.11	0.08	1.28	0.43	2.09
42-80cm	66.2	5.5	28.3	4.92	4.13	22.8	0.57	0.01	0.66	0.59	1.67
80-95cm	65.2	8.0	26.8	5.04	4.18	9.2	0.68	0.02	0.39	0.43	1.16
95cm+	69.4	6.3	24.3	5.18	4.25	12.4	0.77	0.02	0.30	0.59	1.30
Bangouya2											
0-20cm	68.6	9.1	22.3	5.5	4.48	11.1	1.96	0.09	0.40	0.82	1.60
20-50cm	64.8	9.7	25.4	5.42	4.44	8.1	0.99	0.04	0.28	0.72	1.30
50cm+	59.1	11.8	29.0	5.81	5.04	32.7	1.05	0.05	0.03	0.66	0.88
Dabon1											
0-20cm	84.7	4.5	10.7	4.88	4.06	8.5	1.24	0.07	1.57	0.36	2.22
20-35cm	83.1	5.7	11.2	4.98	4.03	7.4	1.06	0.05	1.70	0.32	2.33
35-60cm	86.4	3.4	10.2	5.02	4.23		1.07	0.05	1.08	0.36	1.75
60-95cm	81.8	7.2	11.1	4.98	4.34	9.4	0.44	0.01	0.56	0.29	1.09
95-135cm	82.7	5.2	12.1	5.13	4.36	4.7	0.54	0.01	0.29	0.29	0.83
Dabon2											
0-30cm	65.3	11.5	23.3	5.12	4.16	17	3.19	0.14	1.03	0.35	1.76
30-60cm	64.2	11.8	24.0	5.33	4.34	13.3	1.29	0.13	0.70	0.38	1.48

Analysis of organic manure

The results of the chemical analysis of chicken manure and bat guano are shown in Table 2.

Table 2 Results of the chemical analysis of chicken manure and bat guano.

	Ca mg kg^{-1}	P_2O_5 mg kg^{-1}	K_2O mg kg^{-1}	Na mg kg^{-1}	Mg mg kg^{-1}	Cd mg kg^{-1}	Cr mg kg^{-1}	Cu mg kg^{-1}	Pb mg kg^{-1}	Zn mg kg^{-1}	N_{tot} (%)	C_{tot} (%)
chicken manure	81058	36223	14634	4684	3179	0.83	418	12.80	1.60	105	1.67	32.92
bat guano	868	28490	6061	280	767	0.69	823	260	21.75	115	2.72	21.91

Whereas chicken manure has considerably higher Ca-, K- and Mg-contents, the N-content of bat guano is higher. In comparison with bat guano of several cave deposits in Zimbabwe, the bat guano analyzed in this study showed a lower P_2O_5-content, a fair K_2O-content and a good N-value (Barber, 1991). The results of the chemical analysis of the tested chicken manure reveal a good quality compared with average nutrient contents of chicken manure (Austrian Federal Ministry of Agriculture and Forestry, 1996). Especially the Ca- and the P_2O_5-values are high, while the N-content and the K_2O-content are similar to the average.

Concerning the contents of heavy metals, the high Cr-values of both organic fertilizers, especially of bat guano, could eventually bear the risk of soil contamination in the long term. However, current limits of Cr-contents of organic fertilizers differ widely or have not been fixed yet. Contents of all other heavy metals measured, were sufficiently lower than the limits of current international regulations (European Council, 1986).

Yields and statistical analysis

Plot grain yields and plot biomass production varied considerably also between treatment replications. However, according to statistical analysis, including covariates to the *General Linear Model* of *SPSS for Windows* (Bühl and Zöfel, 1998), neither grain yields nor biomass production were remarkably influenced by differences of plot C-contents or plot N-contents. Variance of grain yields and biomass production between treatment replications was more likely due to other factors, such as high groundwater level (yields in Dabon were significantly lower on plots where soil depth above groundwater level was more shallow).

Grain yields on the control plots were similar to average maize grain yields in Guinea. The mean grain yield of plots where only mineral fertilizer was applied exceeded the mean yield of the control plots, but was not significantly different at the 5% level (Table 3). Consequently, the recommended rate of fertilizer application seems to be too low. Mean grain yields of all other fertilizer treatments were higher than the average yield of plots with sole application of mineral fertilizer. On both sites the highest grain yields were harvested on the plots which had received the chicken manure plus mineral fertilizer treatment. Nevertheless only in Dabon the chicken manure plus mineral fertilizer treatment exceeded the mineral fertilizer treatment significantly at the 5% level.

Table 3 Mean maize grain yields and mean production of dry biomass in Bangouya and Dabon as affected by the different fertilizer treatments.

Grain yield					
Bangouya			Dabon		
Treatment	Mean t ha^{-1}	Ranking*	Treatment	Mean t ha^{-1}	Ranking*
chicken m. plus min. fert.	3.51	a	chicken m. plus min. fert.	4.58	a
bat guano plus min. fert.	3.27	a	bat guano plus min. fert.	3.68	ab
bat guano	3.05	a	chicken manure	3.08	ab
chicken manure	2.91	ab	bat guano	2.52	bc
mineral fertilizer	2.49	ab	mineral fertilizer	2.35	bc
Control	1.77	b	control	0.87	c
Biomass production					
Bangouya			Dabon		
Treatment	Mean t ha^{-1}	Ranking*	Treatment	Mean t ha^{-1}	Ranking*
chicken m. plus min. fert.	14.71	a	chicken manure	15.58	a
chicken manure	13.48	ab	chicken m. plus min. fert.	14.42	a
bat guano plus min. fert.	13.44	ab	bat guano plus min. fert.	8.86	b
bat guano	9.40	abc	mineral fertilizer	8.52	b
mineral fertilizer	8.21	bc	bat guano	5.92	bc
Control	6.06	c	control	3.25	c

*Treatment means followed by a common letter are not significantly different at the 5% level (Tukey Test)

In general good results were obtained with treatments which included the application of chicken manure. Particularly on biomass production the effects of chicken manure were very favourable. In Dabon, biomass production of plots with chicken manure treatment and with chicken manure plus mineral fertilizer treatment was significantly higher than all other treatments. This effect might be due to the positive effects of high Ca content of chicken manure on soil properties, in particular on soil acidity, danger of Al-toxicity and nutrient balance (Fore and Okigbo, 1972).

However, comparison of biomass results and grain yield results of the chicken manure treatment and the chicken manure plus mineral fertilizer treatment suggests that additional easily available nitrogen supplied by mineral fertilizer is necessary for an optimal development of the maize grain yield on the experimental soils.

Guano contains less Ca, Mg, and K, and more N than chicken manure although the N content of guano is dominated by slow release-compounds. Grain yields of guano plots are similar to those obtained on plots with chicken manure application, but biomass production is remarkably lower especially on the experimental field of Dabon. Because of the slow release of plant available nitrogen, positive long term effects can be expected on the plots with guano treatment.

Taking into account the increase of soil organic matter content (Ahn, 1993) and positive long term effects, chicken manure and bat guano applied at the rates used in this field trial are generally an apt or even better alternative compared with conventional fertilizers applied at the currently recommended rate. Still higher yields can be obtained with treatments combining the organic fertilizers with mineral fertilizers (Agboola *et al.*, 1975).

Further research will focus on the confirmation of the yield results of the first experimental year, on the optimization of fertilizer use and on the evaluation of local agrarian systems for the development of new management practices, which will be implemented and tested on on-farm trials (Posner and Crawford, 1992).

Conclusion

Guinea's most important economic sector is agriculture, since the contribution of agriculture to the gross domestic product (GDP) is 24% and a big majority of the population depends on agriculture as working place and living base. Nevertheless Guinea has to import a big share of its food demand. Therefore intensification of agricultural production is one of the main aims of the Guinean government. Effects of two locally available organic fertilizers (bat guano and chicken manure) and conventional mineral fertilizer on yields of maize in low input agriculture were compared on two test sites in the Lower Guinea region of Guinea, West Africa. The climatic conditions in the experimental area are characterized by one rainy season (April until October), and annual rainfall ranging from 3,000 mm to 4,000 mm, with a maximum in July and August. Plinthosol, Ferralsol and Fluvisol were tested with treatments 1. bat guano, 2. chicken manure, 3. mineral fertilizer, 4. bat guano plus mineral fertilizer, 5. chicken manure plus mineral fertilizer, 6. treatment without fertilizer application (control plot), with six repetitions. Results of the first experimental year show that both organic fertilizers resulted as apt or even better alternatives compared with conventional fertilizers. Currently recommended rates of mineral fertilizer application are too low according to the study results. Grain yield and biomass production of maize on plots where treatments included organic manure were raised significantly compared with the control plot.

Mean grain yields of all other fertilizer treatments were higher than the average yield of plots with sole application of mineral fertilizer. On both sites the highest grain yields were harvested on the plots which had received the chicken manure plus mineral fertilizer treatment. Nevertheless only in Dabon the chicken manure plus mineral fertilizer treatment exceeded the mineral fertilizer treatment. Overall the soils of both sites show a very low fertility. Taking into account the increase of soil organic matter content and positive long term effects, chicken manure and bat guano applied at the rates used in this field trial are generally an apt or even better alternative compared with conventional fertilizers applied at the currently recommended rate. Still higher yields can be obtained with treatments combining the organic fertilizers with mineral fertilizers.

Further research will focus on the confirmation of the yield results of the first experimental year, on the optimization of fertilizer use and on the evaluation of local agrarian systems for the development of new management practices, which will be implemented and tested on on-farm trials.

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