Response of Maize to Poultry Manure and Mineral Fertilizer

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Resumé
Agyenim Boateng, S., Kornahrens, M. & Zickermann, J. *La réaction du maïs au fumier et à l'engrais minéral.* L'effet de l'engrais minéral et leur combinaison sur le maïs était évalué dans un essai du pot. Six traitements viz 0, 4, 8, 12 tonnes du fumier ha^{-1}, 60-40-40 kg NPK ha^{-1} (NPK) et 2 t pm ha^{-1} + 30-20-20 kg ha^{-1} (2 t + ½ NPK) étaient évalués dans un dessein complètement randomisé. La matière de la racine sèche de 2 t + ½ NPK était plus grande que celle de 4 t ha^{-1} et le contrôle et le similaire à celle de NPK 8 et 12 t pm ha^{-1} traitment. La biomasse du brin a montré une tendance similaire à la matière de la racine sèche. Les traitements NPK et le niveau 12 t pm ha^{-1} ont possédé les rapports élévés de brins - raciness. Il était remarqué que le NPK a dépassé les autres traitements sur le plan de poids en graine; néanmoins la différence n'était pas significative par rapport à celle du traitemant 2 t + ½NPK 8 et 12 pm. Mille valeurs des poids en graines ne différaient pas statistiquement parmi les traitements. L'indice de récolte a indiqué l'éfficace élévation de la matière sèche qui regroupe dans un évier dans le traitement combiné que dans les niveaux 4 et 8t pm ha^{-1}. Pour les buts pratiques et du point de vue économique, un niveau de 4t pm ha^{-1} est à recommander lorsque le traitement est plein de promesses. Il était remarqué que le fumier apparait plus avantageux s'il s'agit de fournir C et N à la culture subséquente (étant donné que) C et N restèrent plus dans le sol après la récolte du maïs que l'engrais minéral. Le niveau 12 t P M ha^{-1} a retenu plus de 40% N et 25% C que le niveau d'engrais minéral. Les études supplementaires surtout aux situations du terrain sont recommandés.

Mots clés : Le fumier, l'engrais minéral, le maïs, l'essai du pot.

Abstract
The effect of mineral fertilizer, poultry manure, and their combination on maize was evaluated in a pot experiment. Six treatments viz. 0, 4, 8, 12 tons of poultry manure (PM) ha^{-1}, 60-40-40 kg NPK ha^{-1} (NPK) and 2 t PM ha^{-1} + 30-20-20 kg NPK ha^{-1} (2 t + ½ NPK) were used in a completely randomized design. Root dry matter of the 2 t + ½ NPK was greater than that of the 4 t ha^{-1} and control, and similar to that of the NPK, 8 and 12 t PM ha^{-1} treatments. Shoot biomass showed a similar trend as the root dry matter. The NPK treatments and 12 t PM ha^{-1} rate had high shoot-root ratios. Although the NPK outyielded the other treatments in grain weight, it did not differ significantly from that of the 2 t + ½ NPK, 8 and 12 t PM ha^{-1} treatments. Thousand grain weight values did not differ statistically among treatments. The

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harvest index indicated a higher efficiency of dry matter partitioning into sink in the combined treatment than in the 4 and 8 t PM ha^{-1} rates. For practical purposes and from economic point of view, 4 t PM ha^{-1} rate may be recommended while the combined treatment is promising. Poultry manure appeared more advantageous in supplying C and N to the subsequent crop as more C and N remained in the soil after maize harvest than mineral fertilizer. The 12 t PM ha^{-1} rate retained over 40% more N and 25% more C than the mineral fertilizer rate. Further studies, especially in field situations, are recommended.

Keywords: Poultry manure, mineral fertilizer, maize, pot experiment.

Introduction

The traditional farming systems of bush fallowing and shifting cultivation with their reduced fallow periods of 2 - 3 years (Bonsu and Quansah, 1992; Ofori and Fianu, 1996) are no longer efficient in sustaining crop production in Ghana.

Inorganic fertilizer use has been the major means of achieving higher yields of crops. However, these inputs have become so expensive that small-scale farmers, who constitute about 80% of the farming population, cannot afford to buy and apply them.

There is the need to look for alternative methods of improving the soil and crop yields beside the conventional inorganic fertilizer use that has become expensive. Organic manuring has been suggested as a possible method (Brady, 1996; Harwood, 1996).

Poultry manure is an organic manure with high fertilizer value (Yagodin, 1984; Hileman, 1972). Hileman (1972) indicated that poultry manure has been successfully used on a wide variety of crops as the only direct source of plant food, as a supplement to mineral fertilizers or as a soil amendment.

Poultry manure abounds in southern Ghana (MoFA, 1994; Osei, 1995) where poultry farms are increasingly being established. Maize and vegetable growers as well as other crop farmers in this area have begun using manure from these poultry farms.

In a study undertaken by Boateng and Oppong (1995) on the effect of farmyard manure and method of clearing on maize yield, it was found that plots treated with poultry manure and NPK (20-20-0) gave the best yields.

Hemeng *et al.* (1995) observed from a study of organic soil amendment and their multiple benefits to crop production that decrease in soil nematodes in addition to increase in rice yield occurred when the rates of application of poultry manure (0, 1, 2.5 and 5 t ha^{-1}) were increased.

Similarly, Asubonteng and Dennis (1995) reported that poultry manure was as good as mineral fertilizer in increasing yields of rice in inland valleys. One tonne per hectare of poultry manure produced, almost the same amount of paddy rice (5.3 t ha^{-1}) as when 90-60-60 kg N-P-K ha^{-1} was applied on a sandy loam soil in the forest zone. At a rate of 2.5 t ha^{-1} poultry manure, the rice yield was 6.15 t ha^{-1} (95% > control and 16% > 90-60-60 NPK).

Rydin (1985) reported that seedlings of sweet orange (*Citrus sinensis*) and grape fruit (*Citrus paradisi*) grown in pots containing poultry manure increased in height, girth and root growth.

Notwithstanding these and other studies, the response of common food crops such as maize to poultry manure on various soil types is not well-documented in Ghana. The objective of this study was to assess the response of maize to poultry manure and mineral fertilizer on a forest acrisol.

Materials and methods

The experiment was set up in a green house at the Faculty of Agriculture of the Kwame Nkrumah University of Science and Technology, Kumasi, Ghana in 1997. A 17-litre plastic bucket with top and bottom diameters of 32 cm and 22 cm respectively was used. This was filled with 15 kg fresh homogenized topsoil of a Ferric Acrisol (0-20 cm) and packed to a density of 1.2 Mg m^{-3}.

Twenty-four pots made up of six treatments in four replications were used in a completely randomized design (CRD) (Table 1).

The exact amount of nutrients available in each treatment is provided in Table 1. The N was supplied in the form of a compound 20-20-20 NPK fertilizer applied at planting and then topdressed with sulphate of ammonia at six weeks after planting. The manure and mineral fertilizers were mixed with the top 3 cm of soil in the pots. The manure was a decomposed dry material from layer birds in a deep litter system collected from a commercial poultry farm about 20 km away. Two maize (var. Abeleehi) seeds were sown in each pot.

The crop was watered every three days (i.e. day 1, 4, 7, 10, etc.). The water was added in two perforated tubes of 3 cm in diameter, which were installed in each pot in order to provide homogenous wetting and avoid changes in the bulk densities of the soil.

The maize plants were harvested at maturity (*ca.* 110 days). The parameters measured were: root biomass, shoot biomass, grain weight, one-thousand grain weight (TGW) and harvest index (HI). The harvest index was determined by the relationship:

Harvest Index (HI) = Economic yield x (Biological yield)$^{-1}$ ... (1).

Soil samples for analyses were taken at

Table 1. Treatments, amounts of fertilizer and nutrients applied per pot.

Treatments	*Amount of fertilizer*	*Amount of nutrients (NPK)*	*Amount of nutrients (NPK) (kg ha^{-1})*
	g per pot		
Control (absolute)	-	-	-
2 t PM[2] ha^{-1} + 30-20-20 kg NPK ha^{-1}	80 + 7.5 NPK + 2.5 S.A.[1]	3.59/2.11/2.42	78.4/44.6/52.4
60-40-40 kg NPK ha^{-1}	15 NPK + 5 SA	3.30/2.25/2.25	60/40/40
4 t PM ha^{-1}	160	3.87/1.97/2.59	96.8/49.2/64.8
8 t PM ha^{-1}	320	7.74/3.94/5.18	193.6/98.4/129.6
12 t PM ha^{-1}	480	11.62/5.91/7.77	290.4/147.6/194.4

[1] SA - Sulphate of Ammonia (21% N).
[2] PM - Poultry manure.

the beginning and end of the experiment, (i.e. before poultry manure and mineral fertilizer applications and at harvesting of the test crop). Samples were air-dried at room temperature (about 27°C) for four days, crushed and sieved through a 2 mm sieve. Stones, gravels and undecomposed plant parts were discarded.

The pH of the manure and soil was determined on a soil to water ratio of 1:2.5 using a Corning Model 12 pH metre. Organic carbon was determined by the standard Walkley and Black wet oxidation method (Walkley and Black, 1934). Percentage organic matter was calculated by multiplying organic carbon value by 1.724 (van Bemmelen factor). Total nitrogen was assessed by the macro-Kjeldahl's method (Bremner, 1965) involving digestion and distillation. Available phosphorus was determined by the method described by Bray and Kurtz (1945). Exchangeable basic cations were extracted with 1.0 M neutral ammonium acetate solution. Potassium was determined using the flame photometer and calcium and magnesium using the EDTA complexometric titration method (Thomas, 1982).

Data were analysed statistically using MSTATC statistical package (MSTATC, 1988).

Results and Discussion

Nutrient content of poultry manure

The chemical composition of the poultry manure used in the study (Table 2) shows that the poultry manure has levels of properties consistent with poultry manure from other farms; which also

Table 2. Chemical properties of the poultry manure.

Parameter	*Sample used*	*Reported range*[1]
Total N (%)	2.42	2.17-3.50
P (%)	1.23	0.18-1.68
K (%)	1.62	0.90-2.17
Organic C (%)	35.30	26.30-40.69
Organic Matter (%)	61.90	45.39-70.15
Ca (%)	3.35	1.28-4.40
Mg (%)	2.15	1.54-4.70
C/N	14.6	11.3-13.8
pH (1:2.5 H_2O)	7.7	6.8-8.4
Moisture content (%)	11.4	-

[1]Range encountered in final year students' analysis of poultry manure from different poultry farms. *Source:* Quarcoo, A.N.D., 1996. B.Sc. Disssertation.

compare very well with other values obtained from other countries (Perkins and Parker, 1971; Yagodin, 1984; Archer, 1985). Generally, the chemical properties of the manure are medium to high.

Characteristics of the soil

Table 3 shows some of the chemical characteristics of the soil used for the experiment. The soil was moderately fertile, having moderate levels of total N (0.14%), organic C (1.83%) and exchangeable bases, and a high percentage base saturation (92%). It was moderately acidic, having a pH value of 5.4 and compares well with most tropical soils of this nature.

Effects of poultry manure on the soil

Total nitrogen in the soil increased with

Table 3. Some baseline properties of the soil used in the experiment (topsoil 0 - 20cm).

Parameter	*Mean*
pH (H_20)	5.4
Total N (%)	0.14
Org. C (%)	1.83
Organic Matter (%)	3.15
C/N (mg kg^{-1})	13.07
Avail P (mg kg^{-1})	5.4
Exch. Cations (c mol kg^{-1}):	
K	0.2
Ca	13.1
Mg	1.1
Na	0
Exch. Acidity (c mol kg^{-1})	1.2
ECEC (c mol kg^{-1})	15.6
Base saturation (%)	92

increasing rate of application of poultry manure, from 0.13% to 0.21%, an increase of about 60% with the 12 t PM ha^{-1} rate. With the 4 t PM ha^{-1} and 8 t PM ha^{-1} rates, increases were 30% and 46% respectively. The 12 t PM ha^{-1} retained over 40% more N than the mineral fertilizer (Table 4).

The maize crop used up nitrogen for growth and development processes, hence the native nitrogen level for the control decreased, whilst very little amount of the added mineral nitrogen remained in the soil. Relatively more nitrogen remained in the soil with the poultry manure treatments for supply to subsequent crop. Higher increases may be expected with yearly applications over a number of years as has been noted by Prasad and Singh (1980).

Organic carbon did not increase with increasing rate of manure applications up to 4 t ha^{-1}. However, it decreased from 1.83% to values between 1.59% and 1.74%. Tropical soils experience this lowering of organic carbon levels when the vegetative cover is removed (Agboola, 1990; Acquaye, 1992; Ofori, 1995) since there is enhanced decomposition of organic matter. The application of poultry manure appeared advantageous since relatively more organic carbon was made available from the poultry manure treatments for subsequent cropping.

At greater rates of poultry manure, however, greater values of 1.98% and 2.04% were recorded (8% and 11.5% increases respectively from the baseline value). This implies that poultry manure can increase the levels of organic matter of the soil after one season if it is applied at higher rates. The organic carbon obtained for the mineral fertilizer and control treatments were similar. The 12 t

Table 4. Total nitrogen and organic carbon levels of the soil at the end of the experiment.

Treatments	*Total*	*Org. C*	*OM %*	*C/N*
Control	0.13	1.59	2.74	10.27
2 t Pm[1] ha^{-1} + 30-20-20 kg NPK ha^{-1}	0.15	1.63	2.81	10.87
60-40-40 kg NPK ha^{-1}	0.15	1.62	2.74	10.80
4 t PM ha^{-1}	0.17	1.74	3.00	10.24
8 t PM ha^{-1}	0.19	1.98	3.41	10.42
12 t PM ha^{-1}	0.21	2.04	3.52	9.71
LSD (*p*=0.05)	0.02	0.11	0.19	5.5

[1] PM - poultry manure.

PM ha^{-1} retained 25% more C than the mineral fertilizer. Kingery *et al.* (1993) showed that application of manure resulted in increased organic C and N to depths of 15 and 30 cm respectively. A study to investigate the comparative effectiveness of rice shavings, poultry manure and inorganic fertilizers in restoring the productivity of an eroded, low fertility ultisol in South Eastern Nigeria over 3 cropping seasons show that poultry manure significantly increased soil organic carbon, total nitrogen, exchangeable bases and cation exchange capacity during the first cropping season (Mbagwu, 1992). The levels and behaviour of organic matter and organic carbon in the soil after addition of poultry manure are similar. Additions of organic matter to the soil are generally in the form of plant residues, manures and other organic materials (Hayes, 2003). Agboola *et al.* (1975) reported that a moderate application of farmyard manure (no exact figures given) on a crop soil in the rain forest zone was sufficient to slow down decomposition of humus, which progressed only half as fast as with mineral fertilizers. The C/N ratio of the soil, whether or not it received mineral fertilizer or poultry manure, was quite low (around 10). This means that it has few problems with nitrogen availability to the crop growing on it (Cowan, 2004).

Biomass yield

Biomass yields of maize are in Table 5. Root dry matter of the 2 t + ½ NPK was greater than that of the 4 t PM ha^{-1} and control. However, it was similar to that of the NPK, 8 and 12 t PM ha^{-1} treatments. According to Muller-Samann and Kotschi (1994), the fertilizing effect (especially the nitrogen effect) of manure usually lags behind that of the corresponding amount of soluble mineral fertilizers at first, because in the first growing period, only part (30-60%) of the manure nitrogen becomes available. Thus, allowing 60% manure to be available during the growing period of the maize, only 58 kg N ha^{-1} of the 4 t PM ha^{-1} would be available for crop uptake. About 116 and 174 kg N ha^{-1} of the 8 and 12 t rates would respectively be available. Considerable amount of nutrients from these two rates relative to the 4 t ha^{-1} rate was likely to be available for root formation and development. With the 2 t + ½ NPK and NPK treatments 60 kg N ha^{-1} (although not much different in quantity from the 4 t ha^{-1} rate) was readily available for crop uptake and root synthesis.

Shoot biomass outweighed the root biomass in all the treatments and followed a similar trend as that of the roots. Shoot weight appeared to be dependent on the relative amounts of nutrients present in the treatments and their availability in the soil. The 12 t PM ha^{-1} with the largest amount of nutrients and the NPK with the largest nutrient availability had the largest shoot biomass. The combined treatment

Table 5. Biomass and grain yields of maize as affected by poultry manure and mineral fertilizer.

Treatments	*Root biomass*	*Shoot biomass g per pot*	*Grain yield*	*Thousand grain wt (g)*	*Harvest index*
Control	3.5	28.4	2.4 (0.06)[2]	245	0.07
2 t PM[1] ha^{-1} +30-20-20 kg NPK ha^{-1}	18.1	227.5	80.1 (1.84)	267	0.35
60-40-40 kg NPK ha^{-1}	18.9	272.1	116.0 (2.67)	274	0.43
4 t PM ha^{-1}	13.3	142.3	42.3 (0.97)	260	0.30
8 t PM ha^{-1}	21.9	221.0	63.7 (1.4)	273	0.29
12 t PM ha^{-1}	19.9	276.3	103.0 (2.37)	298	0.37
LSD ($p = 0.05$)	4.5	50.4	39.5 (0.91)	53.25	0.21

[1] PM - Poultry manure.
[2] t ha^{-1} in parenthesis.

surpassed the 4 and the 8 t PM ha^{-1} rates (although not significantly different from the latter) probably because of the presence of mineral fertilizer. The 4 t PM ha^{-1} had the least shoot weight among the soil-amended treatments.

The NPK and 2 t PM ha^{-1} + ½ NPK treatments with the largest nutrient availability registered high shoot-root biomass ratios of 14.4 and 12.5 respectively, while the 12 t PM ha^{-1} rate with the largest amount of nutrients had shoot-root ratio of 13.9. The 4 and 8 t PM ha^{-1} treatments had shoot-root ratios of 10.8 and 10.1 respectively. The shoot-root relationship confirmed an important fact that plants grown with high fertilizer concentrations and ample water also have a high shoot-to-root ratio because these plants do not need an extensive root system to take up water and nutrients. Such plants do well in the greenhouse, where ample water and nutrients are available (Pennisi and Van Iersel, 2003).

These observations indicate the superiority of the combined treatment to the 4 t PM ha^{-1} and NPK treatments in biomass production since these treatments supplied equivalent amount of nutrients. It is less cumbersome to apply 2 t ha^{-1} + ½ NPK than 4 t PM ha^{-1} and more economical to procure 2 t PM ha^{-1} + ½ NPK than the sole mineral fertilizer to supply equivalent amount of nutrients (Zickermann *et al.*, 1997).

Grain yields

The grain yields of all treatments were significantly different from the control

(Table 5), signifying the importance of fertilizing or manuring the soil. However, increasing the rate of manure application increased grain yield at a decreasing rate. The grain yield for 8 t PM ha^{-1} (64 g per pot) and 4 t PM ha^{-1} rates (42 g per pot) were not significantly different. Yield from 12 t PM ha^{-1} (103 g per pot) was just more than double of that from 4 t PM ha^{-1}. It appears that for practical purposes and pending field investigations, the 4 t PM ha^{-1} rate should be preferred. An application rate of 4 t PM ha^{-1} has been recommended by GGDP (1990) for maize.

Yields from 12 t PM ha^{-1} and NPK were significantly greater than 4 t PM ha^{-1} treatments. Yield from the combined treatment was greater than that from 4 t PM ha^{-1}, although not significantly different. It was expected that the NPK, 2 t PM ha^{-1} + ½ NPK and 4 t PM ha^{-1} treatments would give similar or comparable yields since they supplied equivalent amount of available of nutrients but this was not the case. Probable reasons may include:

(i) Controlled watering might have reduced leaching of nutrients from the mineral fertilizers, thus, making them more efficient,
(ii) Activities of micro organisms on manure in pots might not be as effective as on the field due to restricted conditions, and
(iii) Soil volume available to the manure for enhanced decomposition and mineralization was quite small in the pots, and so not comparable nutrients as the mineral fertilizer were available for the 4 t PM ha^{-1}.

In general, there seems to be relatively low N use efficiency of the poultry manure and high N use efficiency of the mineral fertilizer in the pots. Rees *et al.* (1993) reported that in pot experimentation, there is an apparent higher N use efficiency of mineral fertilizers than manures because the inorganic fertilizer provides readily available N, which is absorbed by the crop.

The application of poultry manure at 4 and 8 t ha^{-1} rates led to significantly smaller grain yields whereas application of mineral fertilizer gave significantly greater grain yield. Therefore, a relative advantage of mineral fertilization was indicated. The harvest index indicated that more dry matter could be channelled into grain in the case of the mineral fertilizer treatment than the others, underscoring a well-known fact that nutrients are more readily available in mineral fertilizers for use by plants. More nutrients seem to be more readily available in the higher rates of poultry manure application than the lower rates. Both the 4 and 8 t ha^{-1} rates were equally efficient in redistribution of photosynthate into the sink (i.e. grains). Yields from the combined treatment were not significantly different from that of the 12 t PM ha^{-1} and NPK treatments. The possibility of combining low rate of poultry manure (i.e. 2 t) with a low NPK rate (30-20-20) to give a synergistic effect is, promising. Mineral fertilizer application is reduced when poultry manure is used in combination, thus agreeing with the findings of Bandel *et al.* (1972); Baldwin (1975) and Hileman (1967) that when manure is applied, high rates of mineral fertilizers are not necessary. The one thousand grain weights were not affected by either the poultry manure or mineral fertilizer application since values did not differ significantly among treatments.

Conclusion

Poultry manure contains all the basic nutrients necessary for crops and is capable of improving soil structure and yields as well. However, high and stable yields of maize crop could be obtained with application of poultry manure in combination with mineral fertilizers. The combination of a lower rate of poultry manure (i.e. 2 t ha^{-1}) with a half recommended mineral fertilizer rate (i.e. 30-20-20 kg NPK ha^{-1}) showed synergism by producing comparable yields to that of the full mineral fertilizer and higher poultry manure rates. For practical purposes and from economic point of view, 4 t PM ha^{-1} rate may be recommended. With regard to availability of nutrients for subsequent cropping, poultry manure application appeared more beneficial since it retained more nutrients, particularly N, than mineral fertilizer in the soil after crop harvest. Further studies, especially under field conditions, are recommended.

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