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Poultry Manure Effect on Growth and Yield of Maize

S. Agyenim Boateng[1], J. Zickermann[2] and M. Kornahrens[2]
[1]*CSIR, Soil Research Institute, Kwadaso-Kumasi, Ghana*
[2]*Kwame Nkrumah University of Science and Technology, Kumasi, Ghana*

Abstract

The effect of poultry manure application on maize (*Zea mays*) growth and yields was studied on a Ferric Acrisol in the semi-deciduous rain forest zone of Ghana. Eight treatments of 0, 2, 4, 6, 8 tons of poultry manure (pm) per hectare, 60-40-40 kg NPK/ha, 2 × 2 t pm/ha and 2 t pm + 30-20-20 kg NPK/ha were used in a randomized complete block design (RCBD) with five replications. The study showed that poultry manure is a valuable fertilizer and can serve as a suitable alternative to chemical fertilizer in the forest zone of Ghana. Poultry manure treatments produced higher values for height, leaf area index and biomass. The 4 t pm/ha rate produced maize grain yield of 2.07 t/ha which was statistically not different from that of the chemical fertilizer rate (2.29 t/ha) and 6 t pm/ha (2.60 t/ha), while the 6 t pm/ha was not statistically different from the 8 t pm/ha rate. Split application of 4 t pm/ha (i.e. 2 × 2 t pm/ha) and 2 t pm/ha + 30-20-20 kg NPK/ha gave similar biomass and grain yields as the 4 t pm/ha. Poultry manure application registered over 53% increases of N levels in the soil, from 0.09% to 0.14%. Exchangeable cations increased with manure application. The study recommends an application rate of 4 t pm/ha for maize on this type of soil in this agro-ecology.

Introduction

The rising cost of inorganic fertilizers coupled with their inability to condition the soil has directed attention to organic manures in recent times. Poultry manure is organic manure which abounds in the peri-urban areas of southern Ghana. In Kumasi and its environs, there are over 300 poultry farms with a wide range of flock size (Lopez-Real, 1995). Available statistics at the Veterinary Services Department of Ghana (1994) indicate that there were 1.9 million of poultry in Ashanti Region alone and 3.7 million in the Greater Accra Region with a total of 13 million in the whole country. These figures, which have likely increased in recent years, imply that substantial source of poultry manure is available in the country, especially in the urban centres.

The manure so produced is disposed of in several ways, including burning. However, some farmers are aware of the beneficial effects of poultry manure and its release of nutrients for a good response in plant growth. Maize farmers in and around the Central Agricultural Station at Kwadaso as well as those around Nkawie peri-urban areas, all in the Ashanti Region of Ghana, have been fertilizing their crops with poultry manure. In the Accra and Kumasi cities, vegetable growers and horticulturists generally use poultry manure on their crops. The use of poultry manure is, therefore, a popular practice in crop cultivation among some farmers within and around these communities.

However, there seems to be little use of poultry manure nationwide, and there is little knowledge available on the effects of the manure on crops for efficient utilization. More information about this manure is needed to extend to farmers. The study, therefore, seeks to determine some effects of rates of poultry manure application on maize growth and yield.

Materials and methods

The experiment was located at the arable section of the Faculty of Agriculture, University of Science and Technology, Kumasi, on a Ferric Acrisol. The area lies within the semi-deciduous rain forest zone of Ghana with an annual rainfall of 1500–2000 mm. The design was a randomised complete block with five replications having the following treatments:

- Control (absolute) – i.e. no addition of manure or chemical fertilizer
- Chemical fertilizer at the rate of 60-40-40 kg NPK/ha (designated as NPK)

- Two tons poultry manure per hectare (2 t pm/ha)
- 2 t pm/ha + 30-20-20 kg NPK (i.e. 2 t pm/ha + ½ NPK)
- 2 × 2 t pm/ha (i.e. equally split application of 4 t pm/ha; the 2nd portion topdressed at 6 weeks after sowing maize)
- 4 t pm/ha
- 6 t pm/ha
- 8 t pm/ha

The size of a plot per treatment was 5 m × 6 m. Poultry manure (about 11% moisture content) was collected from layer birds in deep litter system from a commercial farm about 20 km away. The manure, semi-decomposed, was point-applied in the planting holes 6 days before sowing maize, the test crop. The maize variety, 'Abeleehi', was sown three seeds per hill and thinned to two later at a spacing of 90 cm × 40 cm, giving a density of six plants/m^2. The chemical fertilizer, as 20-20-20 NPK and sulphate of ammonia, was applied by hill placement. The compound fertilizer was applied as basal fertilizer 10 days after sowing the maize and the straight fertilizer topdressed at 5½ weeks later as it is the custom of the local farmers.

At 4 weeks old of crop growth, the above-ground biomass was measured. Plant height and leaf area were measured at 2 weeks interval from the 4th to the 12th week. Biomass was taken by oven-drying the harvested plant material (stems and leaves) at a temperature of 70 °C for 3 days. The plant heights and leaf areas were measured using a tape measure and leaf area meter, respectively. From the leaf area measured, leaf area index (LAI) was determined using the relationship below by Shortall & Liebhardt (1975):

$$\text{LAI} = Y \times N \times A_L \times (A_P)^{-1}$$

where,

Y = population of plants per plot
N = average number of leaves
A_L = average area per leaf
A_P = area of plot

At maturity (105 days after planting), the plants were finally harvested. Final biomass (i.e. stover) and grain yields, harvest index (determined by the relationship: *Harvest index = Economic yield/Biological yield*) and thousand grain weight were determined as yield characteristics. Growth and yield data were analyzed using two-way analysis of variance.

Soil samples were taken using auger from a depth of 0–20 cm at the start and end of the experiment. Soil samples were air-dried, ground and sieved to pass through a 2-mm sieve. The following chemical analyses were done on the soil samples and the poultry manure, using standard laboratory methods: soil *p*H (soil: water ratio of 1:25); organic carbon; total nitrogen, electrical conductivity and ammonium concentration (for the manure only); available P (using Bray-1 method), exchangeable basic cations; exchangeable acidity and effective cation exchange capacity (by summation method). Particle size analysis, bulk density and available moisture content as physical properties were determined on the soil.

The natural vegetation at the site consisted of *Panicum maximum*. The weed residues of *P. maximum* plant material were spread evenly on each of the experimental plots at a rate of 0.5 kg/m^2 before planting. This rate is manageable and considered adequate for a significant reduction in erosion by heavy rainfall (Morgan, 1986). The plant material was analyzed for its N, P and K contents by methods as already described.

Results and discussion

Analysis of the poultry manure

The chemical composition of the poultry manure used in this study is presented in Table 1a. The poultry manure had properties consistent with those poultry manures from other farms and also compared very well with values obtained from other countries (Perkins & Parker, 1971; Yagodin, 1984; Archer, 1985; Mitchell & Donald, 1995). The poultry manure used was generally high in the major nutrients. The high calcium content was probably responsible for the relatively high *p*H. The electrical conductivity level was high (Hileman, 1971) while the ammonium content was low.

TABLE 1a

Some chemical properties of poultry manure used in the study

Parameter	*Levels of sample used*	*Reported range**
N, %2.42	2.17 – 3.50	
NH_4^+, %	0.12	–
P_2O_5, %	1.23	0.18 – 1.68
K_2O, %	1.62	0.90 - 2.17
Ca, %3.62	1.28 – 4.40	
Mg, %	2.15	1.54 – 2.96
Mn, %	0.03	0.02 – 0.03
Org. C, %	35.30	26.30 – 40.70
OM, %	61.90	45.40 – 70.20
C/N ratio	14.60	11.30 – 13.80
eC (mS/cm)	5.50	2.90 – 6.50
*p*H (H_2O, 1:10)	7.70	6.80 – 8.40

*Range encountered in final year student's analysis of poultry manures from different farms (Quarcoo, 1996).

Analysis of the Panicum maximum

Table 1b shows the nutrient content of the plant residues of *P. maximum* left on the experimental plots to prevent possible effects of soil erosion. Although the N, P and K contents appeared low, for practical purposes, it is important to consider the input contribution of the various nutrients via *P. maximum* into the soil.

TABLE 1b

Nutrient content of ***Panicum maximum*** *(0.5 kg dry matter/m^2)*

Parameter	*Levels*
C, %	1.5
N, %	0.47
P_2O_5, %	0.05
K_2O, %	0.54
C/N	88.3

Analysis of the soil

Some physical and chemical properties of the soil are presented in Table 2. The soil was sandy clay. The ratio of silt to clay was very wide (i.e. silt-clay-quotient was low) indicating that the soil was highly weathered and that oligotrophic conditions existed (Pagel *et al.*, 1982). The relatively low *p*H (4.3) is typical for Ferric

Acrisols (Sillanpää, 1982) and may be responsible for the low exchangeable acidity level. The organic carbon, total nitrogen and available phosphorus contents of the soil were low (Pagel *et al*., 1982). The soil was generally low in exchangeable bases. The low potassium content was probably due to the low levels of illitic clay minerals in the soil. The effective cation exchange capacity of 1.57 was very low when compared with the threshold level of 4 c mol (+) kg^{-1}. The base saturation value of 67% was, however, average (Pagel *et al.*, 1982).

TABLE 2

*Some physical and chemical properties of the soil at the start of the experiment (top 0–20 cm)**

Parameter	*Level*
*p*H (H_2O)	4.3
Org. C, %	1.27
Total N, %	0.09
Available P, mg/kg	10.8
Exchangeable cations (c mol/kg)	
K	0.02
Ca	0.95
Mg	0.06
Na	0.02
(Al + H)	0.52
ECEC	1.57
Base saturation %	67
Particle size %	
Sand	64.5
Silt	8.5
Clay	27.0
Bulk density, Mg m^{-3}	1.57

*Values were taken from bulked samples

Effect of poultry manure on the chemical properties of the soil

Soil analysis after harvesting the maize crop showed that organic matter level decreased (Table 3). This may be due to the removal of the vegetative cover as has been noted by some investigators such as Agboola (1990) and Ofori (1995) that there is a decrease in organic matter level of tropical soils when the vegetation is removed. Nitrogen level increased from 0.09% to 0.14% in all the manure treatments. An increase at 0 t pm/ha was also observed; this was probably due to the addition of the *P. maximum.* With lowered P after cultivation, most probably due to crop uptake (since maize is a heavy P feeder), fixation by Al, Fe and Mn oxides and hydroxides (soil being acidic) and immobilization by microorganisms (Lalljee & D'Costa, 1995), addition of the manure to give an increase of 31% over the control showed positive signs of applying poultry manure to the soil.

With the exchangeable cations, potassium and sodium levels increased about four times and remained constant at all rates of manure and fertilizer application. The release of nutrients to the soil by *P. maximum* (Table 1b) most probably explains the increases in K and N, as well as other nutrients at 0 t pm/ha even after cropping as the control also received *P. maximum* residues. The fourfold increase of exchangeable K over the control was probably mainly from the manure and the fertilizer. Magnesium and calcium levels increased with rate of manure application with that of Mg being more pronounced. The change in calcium was observed at the 4 and 8 t/ha rates to be 42% and 52%, respectively, while Mg increases were over 100%. These changes in K, Ca and Mg upon application of poultry manure have been reported by several authors (e.g. Hileman, 1970, 1972; Obi & Ebo, 1995; Pool *et al*., 2000).

The *p*H levels were expected to rise with the addition of the organic manure due to release of ammonia from the decomposing manure (Hileman, 1972) and the Ca level of the poultry manure. However, only slight increases from 4.3 to 4.5 and 4.6 were observed, probably because of the low ammonium content and the buffer capacity of the manure.

Effect of poultry manure on some physical properties of the soil

Two main physical properties were measured: moisture content (i.e. plant available water) and bulk density (Table 4). Application of poultry manure increased moisture content of the soil with 8 t pm/ha having a little edge over 4 t pm/ha; both doing better than the chemical fertilizer. Poultry manure, with its high organic carbon content, adds organic matter to the soil. Organic matter has the ability to retain appreciable amounts of soil moisture, hence, probably the rise in level of moisture content of soil upon application of the manure. This positive change in soil moisture content due to poultry manure addition has been reported by Yagodin (1994).

TABLE 4

Effect of poultry manure on moisture content and bulk density of the soil

Treatment	*Plant available water (%)*	*Bulk density ($Mg\ m^{-3}$)*
Control	9.53 (9.60)*	1.56 (1.57)*
4 t pm/ha	10.27	1.54
8 t pm/ha	10.76	1.53
NPK	9.94	1.55
2 t pm/ha + ½ NPK	9.95	1.55

*Values at the start of the experiment are shown in brackets. All values were from bulked samples of treatments.

Bulk density values were slightly lowered by the manure (from 1.57 to 1.55–1.53 Mg m^{-3}). Although the rise was not much, it gave a positive sign of what poultry manure could do to soils with high bulk densities. Obi & Ebo (1995) reported that addition of poultry manure to the soil significantly decreased soil bulk density. Thus, it can be concluded that poultry manure has favourable effects on the moisture content and bulk densities of Ferric Acrisols. High moisture contents and lower bulk densities are good soil characteristics for good plant growth.

Biomass assessment

At 4 weeks old, the maize plants were randomly sampled for above-ground biomass determination (Fig. 1). Above-ground biomass was highest on plots with poultry manure; the higher rates (i.e. 4, 6 and 8 t/ha) having more biomass than the lower rate (i.e. 2 t/ha). The control had the lowest biomass while the poultry manure in combination with chemical fertilizer had the highest probably due to synergy. Among the high rates of poultry manure the biomass decreased with increasing rate of application, the 4 t/ha rate having the highest biomass. Probably, it was too early at this stage to assign cogent reasons why these were observed.

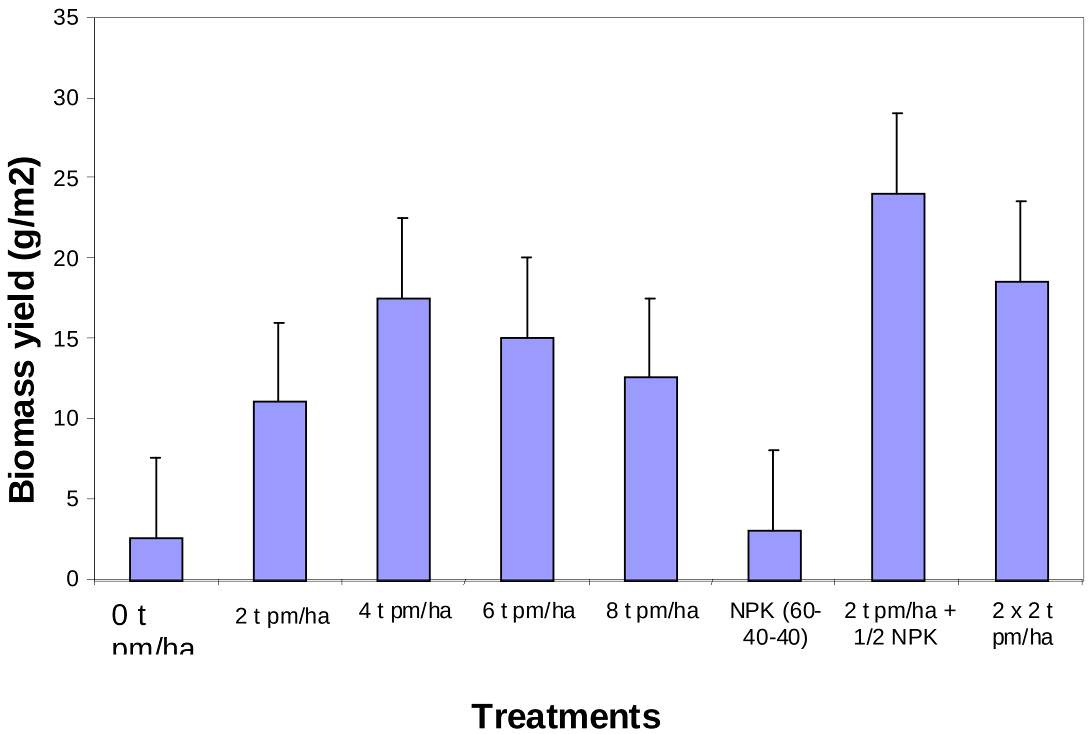
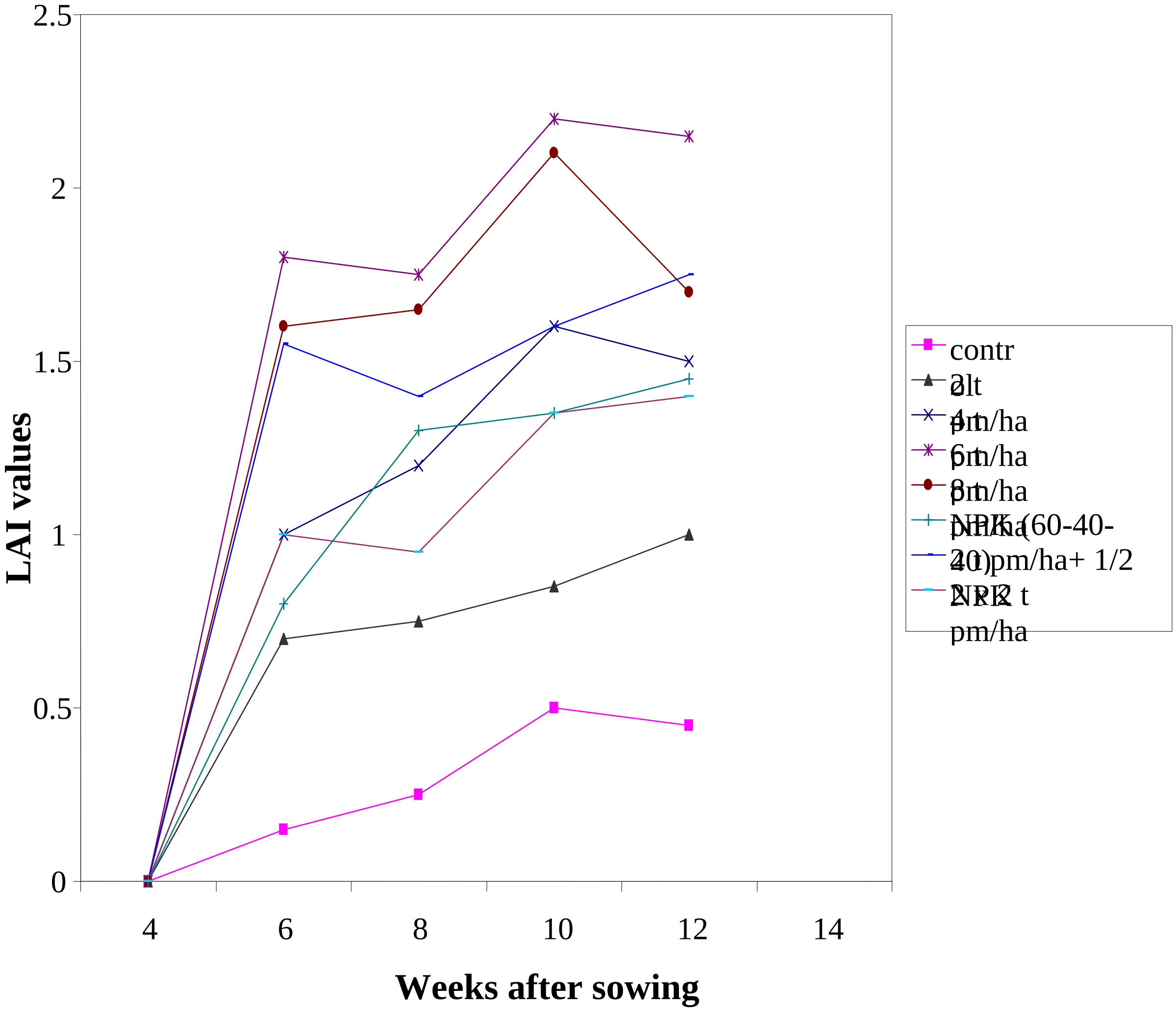
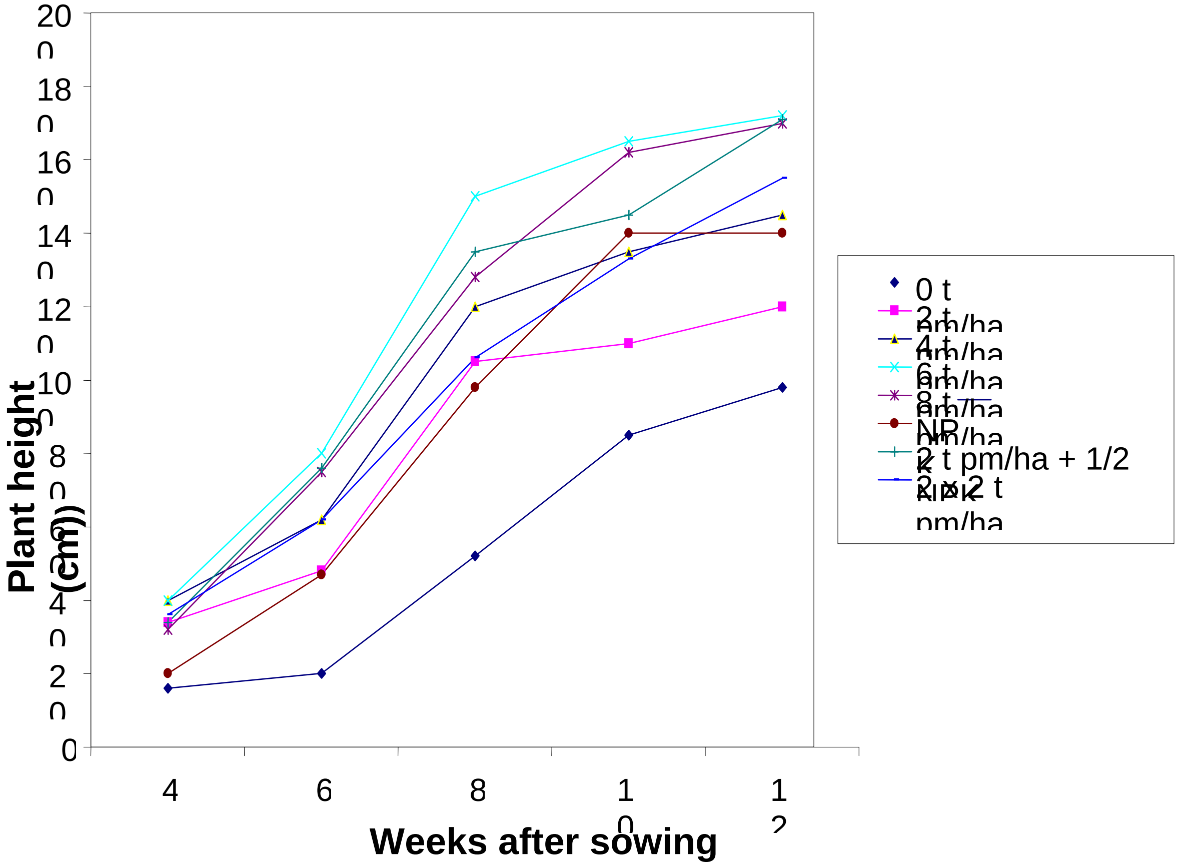


Fig. 1. Changes in total above-ground biomass of 4-week old maize plants under different poultry manure treatments.

Leaf area index (LAI) and height

According to Shortall & Liebhardt (1975), LAI and grain yield are positively correlated as long as the LAI is below 5, hence, the need to measure LAI. Fig. 2 and 3, respectively, show the LAI and height of maize plants at various stages of growth. About 75% of the maximal leaf area was produced before the 6th week for 6, 8 t pm/ha and 2 t pm/ha + ½ NPK rates. The highest LAI was 2.1 reached by 6 t pm/ha at the 10th week followed closely by the 8 and 4 t/ha rates, while the lowest LAI of 0.6 was registered by the control. These observations, though values were low, indicate that the LAI was significantly influenced by the application of poultry manure and mineral fertilizer. It appeared that the 6 t/ha rate was emerging as a better choice than 8 t/ha probably due to a phenomenon of decreasing returns.


LAI values
2.5
2
1.5
1
0.5
0
4
6
8
10
12
14
Weeks after sowing


Plant height (cm)
20
18
16
14
12
10
8
4
2
0
4
6
8
Weeks after sowing
0 t
2 t pm/ha
4 t pm/ha
6 t pm/ha
8 t pm/ha
NPK
2 t pm/ha + 1/2 NPK
2 x 2 t pm/ha

Mulebo *et al.* (1983) achieved LAI of 4.4 with tropical maize (six plants/m^2 and one plant per stand). The relatively low LAI of the variety Abeleehi in this study might be due to low leaf area values which might have resulted from the relatively low rainfall (total amount from May to August was 511 mm; the average being 700–900 mm) experienced in the period.

The height also followed a similar trend with the tallest plants from the 6 t pm/ha rate and shortest from the control. Values from 2 × 2 t pm/ha and 2 t pm/ha and 2 t pm/ha + ½ NPK compared very well with that of the 6 and 8 t pm/ha rates. Obi & Ebo (1995) noted significant improved average maize height upon application of poultry manure to a severely degraded ultisol in southern Nigeria.

Final maize biomass yield

Table 5 summarizes the results obtained during the final harvest of maize plants. Dry biomass gains were in the order – 6t/ha > 8 t/ha > 2 t/ha + ½ NPK > NPK > 4 t/ha > 2 × 2 t/ha > 2 t/ha > control. This showed that poultry manure and chemical fertilizer improved biomass yield. There were no significant differences among 6 t/ha, 8 t/ha and 2 t/ha + ½ NPK treatments. The differences among NPK, 4 t/ha and 2 t/ha + ½ NPK treatments were also not statistically significant.

The results indicate that poultry manure at a rate of 4 t/ha has the potential to improve maize yields significantly over control. This poultry manure rate may serve as an alternative to chemical fertilizer at the rate used in this study and may be recommended. This is because the increase in rate of application of the manure beyond 4 t/ha did not result in significantly proportional increase in biomass yield, i.e. dry matter gains decreased at an increasing rate of manure application above 4 t/ha. It may also not be very practicable for peasant farmers to use as high poultry manure rate as 8 t/ha. It may be noted that manure application of 4 t/ha is relatively easier than application of 2 t + ½ NPK/ha.

The lowest poultry manure rate plus one-half rate of chemical fertilizer (i.e. 2 t/ha + ½ NPK) yielded significantly higher than the full dose of NPK alone. This implies that integrated application of organic and inorganic fertilizers might be more desirable than either type of fertilizers alone. In such cases, synergism might be at work. This is in agreement with the finding of Vasanthi & Kumaraswamy (2000) who reported that poultry manure plus one-half rate of the chemical fertilizer rate yielded significantly greater amount of green fodder of corn than the full rate of NPK alone.

Grain yields

The grain yields of maize are also presented in Table 5. Grain yields (although much lower than the real yield potential of 4.6 t ha^{-1} (GGDP, 1991)) also followed the same trend as that of the biomass. All the treatments had significant improvement over control signifying the importance of fertilizing or manuring the soil in maize production.

TABLE 5

Some yield parameters of maize

Treatment	*Biomass t/ha*	*Grain*	*Thousand Grain Weight g*	*Harvest Index (HI)*
Control	1.35a	0.44a	211.50ab	0.31
2 t pm/ha	2.62ab	1.04a	210.60a	0.33
2 x 2 t pm/ha	4.51b	1.92b	234.56ab	0.43

4 t pm/ha	5.78bc	2.07b	238.72b	0.48
NPK	3.60b	2.29bc	224.90ab	0.41
2 t pm/ha + ½ NPK	6.59c	2.31bc	228.42a	0.40
6 t pm/ha	7.13c	2.60bc	251.72b	0.40
8 t pm/ha	5.58bc	3.08c	250.12b	0.43
lsd (p = 0.05)	2.07	0.88	25.73	

Means in the same column followed by different letters are significantly different

The lowest rate of manure application (2 t/ha) improved yield by 136% over the control. Grain yield increased with rate of manure application. However, yield increases were not significantly different among treatments except the control and 2 t/ha which were significantly lower. The NPK and 2 t pm/ha + ½ NPK treatments produced similar yields of 2.3 t/ha but these treatments were not significantly different from the 4 t pm/ha (2.07 t/ha grain yield) and the 2 × 2 t pm/ha (1.9 t/ha grain). Yields from the 4 t pm/ha and the 2 x 2 t pm/ha were similar. The 2 × 2 t pm/ha and the 4 t pm/ha treatments produced grain yield that were not significantly different from that of 6 t pm/ha. The 8 t pm/ha treatment gave the highest grain yield (3.1 t/ha), but it was not statistically different from yield of treatments 6 t pm/ha, 2 t pm/ha + ½ NPK and NPK. The percentage increases over the control, however, indicated the relative advantage of applying poultry manure and that an application rate of 2 t/ha may be useful. The 2 t pm/ha rate was able to substitute almost 50% of mineral fertilizer without limiting grain yield.

Table 5 suggests that poultry manure application rate of 4 t/ha was the most effective. This is because as the yields (biomass and grain) increased linearly up to this level of application, higher applications to 6 and 8 t pm/ha continued to increase maize yields at a reduced rate, a probable case of diminishing returns. The thousand grain weight was in the order 6 t/ha > 8 t/ha > 4 t/ha > 2 × 2 t/ha > 2 t/ha + ½ NPK > NPK > control > 2 t/ha. There were no significant differences among 4, 6 and 8 t/ha rates; hence 4 t/ha was most effective. The harvest index (HI), which is the relationship of the economic yield (grain) to the above-ground biomass, indicated that the 4 t/ha with the highest value of 0.48 was most effective, since a low HI indicates a low efficiency of translocation of assimilates (Lucas, 1984). Thus, lower values by 6 and 8 t/ha rates confirm the higher efficiency of 4 t/ha.

Split application of 4 t pm/ha or 2 × 2 t pm/ha (i.e. twice with 2 t pm/ha, the first being made before sowing and the second 6 weeks after sowing as topdress) gave almost the same grain yields as single application of 4 t pm/ha, and may also be recom-mended. It is similarly supported by the thousand grain weight and harvest index values. Splitting manure application may be an advantage if there is not enough manure available at the beginning of the cropping season.

There is also the possibility of combining low rate of poultry manure (i.e. 2 t) with a low NPK rate (30-20-20 kg). In this way, chemical fertilizer application is reduced (Bandel *et al*., 1972; Baldwin, 1975; Hileman, 1967), thereby, precluding excessive salt concentrations in the soil solution (Yagodin, 1984) and most probably reducing costs.

Conclusion

The study indicates that poultry manure is a valuable fertilizer whose use needs to be encouraged. An application rate of 2 t/ha was capable of increasing yields by more than 100% over the control. The 4 t pm/ha may be recommended for now since it produced grain yields similar to the chemical fertilizer rate. Split application of 4 t pm/ha is also recommended when farmers do not obtain enough 4 t pm/ha at the beginning of cropping season. Preferably, 2 t pm/ha + 30-20-20 kg NPK/ha should be recommended because of the complementary and synergistic effects of the organic and inorganic fertilizers. It may be worthwhile considering point application of poultry manure as is done with inorganic fertilizers in order to minimize manure wastage. More research into poultry manure, especially rates and method of application on different crops, and storage/composting process, is needed.

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