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Yield performance of crops and soil chemical changes under fertilizer treatments in a mixed cropping system

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Yields of maize, melon, cassava and cowpea as well as changes in soil chemical contents were examined under different fertilizer treatments in a mixed cropping system. The results showed that fertilizer treatments had significant effects on the yields of maize, cassava and cowpea but no significant effect on melon yield. Total nitrogen decreased in all the plots after cropping and available phosphorus reduced from initial value of 4.72 mg/kg to between 3.37 mg/kg where no fertilizer was added and 3.83 mg/kg under inorganic fertilizer. Exchangeable potassium decreased in all the plots irrespective of fertilizer type and the changes ranged between 25% under organic fertilizer and 53% under inorganic fertilizer treatment. The level of organic carbon decreased by about 17% under organic fertilizer but by 59% where inorganic fertilizer was applied. Calcium (Ca) and magnesium (Mg) increased by 21% and 20%, respectively with the application of organic fertilizer. Though yields of crops increased with application of inorganic fertilizer, organic fertilizer and combination of both in this experiment, changes in soil nutrients status after cropping showed that the fertilizer rates used might not be able to sustain soil fertility under the system.

Key words: Organic fertilizer, inorganic fertilizer, mixed cropping.

INTRODUCTION

Increased cropping intensity had been found to accentuate changes such as rapid increase in weed growth, erosion of top soil, degradation in soil physical condition, deterioration of nutrient status and changes in the number and composition of soil organisms (Ayoub, 1999). Judicious management and conservation of soil to guide against these problems that eventually lead to decreased crop yield under intensive cropping have become major areas of agronomic research, more so under multiple cropping where utilization efficiency of different nutrients, in comparison to sole cropping, increases recovery of fertilizer (Brecht and McDonald, 1994). Complementary use of organic manures and mineral fertilizers had proved to be a sound soil fertility management strategy in many countries of the world (Lombin et al., 1991). This is because the use of mineral fertilizer alone has not been helpful under intensive agriculture for it is often associated with reduced yield, soil acidity and nutrient imbalance. Crop response to applied fertilizer depends on soil organic matter and it has been observed that the higher the organic matter content of the soil, the higher the yield of crop (Agboola and Omueti, 1982). A system integrating

different practices of soil fertility maintenance is however required under intensive cropping and this will include the use of mineral fertilizer, organic manures and mixed cropping which provides a fast and good ground cover as well as allowing the roots to exploit soil nutrients at various depths (Steiner, 1991). This study therefore examined the yields of maize, melon, cassava and cowpea as well as changes in soil chemical contents under different fertilizer treatments in a mixed cropping system.

MATERIALS AND METHODS

Experimental site

The study was conducted in the Teaching and Research farm of the University of Ibadan in the south west zone of Nigeria (latitude 7°30'N and longitude 3°54'E). The annual rainfall ranged between 1000 and 1,600 mm while the mean annual temperature ranged between 19.1 and 35.3°C. The site had been cultivated with arable crops such as maize, cassava and legumes with little or no fertilizer and inconsistent fallow periods for some years. It was covered by weeds such as *Panicum maximum*, *Mucuna mucunoides*, *Euphorbia heterophylla* and *Chromolaena odorata* before the commencement

Table 1. Initial chemical and physical characteristics of the soil at the experimental site.

Parameter	Value
pH (H ₂ O)	5.70
Total N (%)	0.18
Organic C (%)	1.75
Available P (mg kg ⁻¹)	4.72
Exchangeable K (cmol kg ⁻¹)	0.36
Exchangeable Ca (cmol kg ⁻¹)	3.75
Exchangeable Mg (cmol kg ⁻¹)	2.44
Exchangeable Na (cmol kg ⁻¹)	0.57
Exchangeable acidity (H ⁺) (cmol kg ⁻¹)	0.12
ECEC (cmol kg ⁻¹)	7.24
Sand (%)	85.00
Silt (%)	7.40
Clay (%)	7.60

Exchangeable ECEC (cmol kg⁻¹)

of this study. The soil of the site belongs to the broad group Alfisol (USDA, 1975).

Soil sampling and analysis

Top soil samples (0-15 cm depth) were taken from the experimental site before planting and at the end of the experiment. Twenty core samples collected randomly were mixed inside a plastic bucket and a composite sample was taken first before cropping while samples were taken per plot after cropping at the end of the second year.

The samples were air-dried, crushed and sieved through a 2 mm sieve. Routine analyses were carried out. Samples were analyzed in the laboratory for some physical and chemical properties using the procedures described in the laboratory manual of the International Institute of Tropical Agriculture (IITA, 1979). Particle size distribution was carried out by hydrometer method while soil pH was measured with the glass-electrode pH meter on 1:1 soil-solution mixture. The total nitrogen (N) was determined by regular macro – kjeldahl method and available P (mgkg⁻¹) was determined by the Bray 1 method. The organic Carbon was determined by Walkey-Black method while the exchangeable cations were extracted with 1 NNH₄OAc solution. Potassium (K), Ca, and Na were measured with the flame photometer and Mg was determined on the atomic absorption spectrophotometer. Exchangeable acidity (H⁺) of the soil was determined by titration method. Effective cation exchange capacity (ECEC) was established as the sum of the exchangeable cations K, Na, Ca, Mg and H⁺ expressed in cmol kg⁻¹ of soil. The results of the analysis are in Table 1.

Experimental design

The experiments were laid out in a randomized complete block design with three fertilizer types: organic fertilizer, inorganic fertilizer, inorganic + organic fertilizer and a control (no fertilizer). Inorganic fertilizer was supplied in the form of 400 kg/ha NPK 15-15-15 based on recommendations for cassava/maize/melon mixture (Fondufe, 1995). Organic fertilizer was a mixture of decomposed poultry manure and urban refuse (1:1) at the rate of 5 t/ha/year (FPDD, 1989). It contained 1.65% N, 0.52% P, 0.91% K, 0.26% Ca, 0.25% Mg and 34.5% organic C. Inorganic + organic fertilizer consisted of 200 kg/ha NPK 15-15-

15 and 2.5 t/ha organic fertilizer (that is, half of inorganic and organic fertilizers rates combined). Organic fertilizer was applied a week before planting. It was uniformly spread on the plots and lightly worked into the soil with hoe. Inorganic fertilizer was applied 3 weeks after planting by ringing around maize plant. The plot size was 24 m².

Planting

Cassava variety TMS 30555 was planted with maize variety DMR-LSR-Y and a local variety of melon (egusi) on the same plot in the early season. Ife-brown variety of cowpea was relayed into cassava at 18 weeks after planting when maize and melon had been harvested in the late season. Planting was done on the flat. The trial was conducted for two consecutive years. Maize and melon were planted at a spacing of 1 m x 1 m at 2 plants /stand to achieve plant population of 20,000 plants ha⁻¹ for each of the crop. Plant population for cowpea was 66,666 plants ha⁻¹ from a spacing of 0.5 m x 0.3 m with 1 plant per stand. Cassava was planted at a spacing of 1 m x 1 m to obtain a plant population of 10,000 plants ha⁻¹. The plots were weeded manually whenever necessary throughout the experimental period. Cowpea pests (insects) were controlled with Karate[®] (Lambda – cyhalothrin) at the rate of 800 ml/ha. Spraying was commenced 5 weeks after planting at 1 week interval until full pod formation.

Maize was harvested fresh at 12 weeks after planting and it was dried to 14% moisture content to obtain dry grain weight. Melon was harvested and processed at 5 months after planting. The seeds were sun dried and weighed. Ripe and dry pods of cowpea were picked as from the 10th week of planting to avoid shattering and weevil infestation. Cassava was harvested 12 months after planting.

Data analysis

Statistical analysis of data was done using analysis of variance (ANOVA) procedure and means were compared using LSD (Least Significant Difference) at 0.05 level of probability when the F - ratio was significant.

RESULTS AND DISCUSSION

Yields of crops

The highest yield of maize was obtained from inorganic + organic fertilizer. It had earlier been reported that nutrients from mineral fertilizers enhanced the establishment of crops while those from mineralization of organic manure promoted yield when both fertilizers were combined (Titiloye, 1982). Maize yield was statistically similar under inorganic and inorganic + organic fertilizer treatments (Table 2). This is because nutrients were readily released from inorganic fertilizer and maize being an aggressive feeder was able to utilize it for its growth and yield. Yield of maize (1344 kg/ha) obtained from organic fertilizer treatment was statistically similar to that (1136 kg/ha) of the control plot showing that maize did not benefit much from organic fertilizer added probably because of low mineralization of nutrient from this source. Chung et al. (2000) also found that organic waste/fertilizer alone could hardly be depended upon as the

Table 2. Yield (kg/ha) of crops as affected by fertilizer types.

Fertilizer	Maize	Melon	Cassava	Cowpea
No fertilizer	1136 ^b	203 ^a	7327 ^d	394 ^b
Organic + inorganic	2338 ^a	231 ^a	9983 ^a	465 ^a
Organic fertilizer	1342 ^b	217 ^a	9202 ^b	408 ^b
Inorganic fertilizer	2144 ^a	224 ^a	8509 ^c	414 ^b

Values in the same column accompanied by the same letter are not significantly different (LSD, 0.05).

Table 3. Changes in soil chemical properties with different fertilizers.

Fertilizer	N (%)	P (ppm)	K (cmolKg ⁻¹)	Organic C (%)	Ca (cmolKg ⁻¹)	Mg (cmolKg ⁻¹)
Initial	0.18	4.72	0.36	1.75	3.75	2.44
No Fertilizer	0.09 ^b	3.37 ^b	0.18 ^b	0.93 ^c	3.43 ^b	2.23 ^b
Organic + inorganic	0.13 ^a	3.52 ^a	0.26 ^a	0.99 ^b	3.51 ^b	2.28 ^b
Organic fertilizer	0.10 ^b	3.77 ^a	0.27 ^a	1.46 ^a	4.53 ^a	2.94 ^a
Inorganic fertilizer	0.08 ^c	3.83 ^a	0.17 ^b	0.72 ^d	2.71 ^c	1.77 ^c

Values in the same column accompanied by the same letter are not significantly different (LSD, 0.05).

sole source of nutrient for corn (maize). The yield of maize was least in unfertilized plots. This could be attributed to removal of nutrient by the harvested crops without any replacement.

Yields of melon were not significantly different under inorganic and inorganic + organic fertilizer treatments (Table 2). Melon however benefited from organic fertilizer applied since yield obtained from that treatment was significantly higher than that obtained from control. The highest cassava root yields were obtained from inorganic + organic fertilizer treatment but the least yield was recorded where no fertilizer was added. Cassava yield from organic fertilizer treatment was significantly higher than yield from inorganic fertilizer treatments. The highest cowpea yield was obtained from combination of inorganic and organic fertilizer but yields from the other fertilizer treatments were not different from the control (no fertilizer) (Table 2). Murwira and Kirchman (1993) had observed that nutrient use efficiency could be increased through combination of manure and mineral fertilizer. Yields of melon, cassava and cowpea increased with addition of organic fertilizer alone. It has been observed that addition of manure increase soil water holding capacity and this means that nutrient would be made available to crops in soils where manure has been added (Costa et al., 1991).

Changes in soil nutrient status

Total nitrogen decreased in all the plots after cropping. It decreased by 55% under inorganic fertilizer treatment while the least reduction (28%) was from inorganic + organic fertilizer treatment (Table 3). Nutrients from

inorganic fertilizer source were readily available compared to that from organic source. It had been reported that N is taken up faster and therefore competed for under intercropping system (Iwueke, 1991). Organic Carbon decreased by about 59, 47, 43 and 17% under inorganic fertilizer, inorganic + organic fertilizer, no fertilizer and organic fertilizer, respectively (Table 3). Low depletion in organic C where organic fertilizer was applied showed that incorporation of organic fertilizer into the soil could be an efficient way of maintaining desired soil organic matter status. Organic C and total N depleted most in plots treated with inorganic fertilizer and this could be as a result of stimulated decomposition of soil organic matter and crop residue by the applied fertilizer leading to higher N mineralization. This could result in higher N uptake by crops and/or leaching loss. This was supported by earlier observations that continuous use of inorganic fertilizer alone brought about rapid deterioration of soil organic matter (Agboola and Corey, 1973). Available P reduced the most where no fertilizer was added and least under inorganic fertilizer (Table 3) and this could be due to crop removal. Depletion in available P in a mixture of cassava/maize/melon/okra had been earlier attributed to crop removal and P – fixation (Ikeorgu, 1984). Exchangeable K decreased in all the plots irrespective of fertilizer type and the changes ranged between 25% under organic fertilizer and 53% under inorganic fertilizer treatment (Table 3). High demand for exchangeable K was reported after maize and melon had been harvested in a cassava/maize/melon mixture (Adeyemi, 1991). This was attributed to the absorption of this nutrient for growth and development of cassava storage root. It was also discovered that K was removed in largest quantity by cassava

followed by N but removal of P was extremely low (Obigbesan, 1977). It follows therefore that the combined demands of cassava and 2 or 3 companion crops for these nutrients would cause a steady decrease in the nutrients during the growing season.

Exchangeable Ca increased by about 21% in plots treated with organic fertilizer after cropping but it reduced in all other plots. This increase could be attributed to the addition of organic fertilizer. Reduction in exchangeable Mg was more under inorganic fertilizer compared with any other treatment including the control. Aggregate uptake of each nutrient was earlier found to be higher in the intercrop of cassava/maize/melon than in the sole crops which showed that soil nutrient reserves would deplete faster under crop mixture than sole cropping unless a commensurate fertilizer regime is maintained (Iwueke, 1991).

Yields of crops were increased by the application of inorganic and organic fertilizers in this experiment but the changes in soil nutrient status after cropping have shown that the system might not be sustainable at the fertilizer rates used. There seems to be a need to increase the rate of organic fertilizer added so as to sustain such intensification involving many crops.

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