Comparative effectiveness of nitrogen applied as straight and in compound fertilizers on maize on a coastal savanna ultisol

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SUMMARY

The effectiveness of N applied as urea, sulphate of ammonia and in the compound fertilizers, 15-15-15 and 20-20-0 at 0, 60 and 120 kg N/ha on maize (cv. Abeleehi) was evaluated on an Ultisol in the Central Region of Ghana. The results showed that 15-15-15 was significantly superior to the other fertilizers tested in terms of crop yield and total nutrient uptake by the maize crop. The soil *p*H was significantly reduced by the application of sulphate of ammonia. Increasing the rate of nitrogen beyond 60 kg/ha had no advantage on the parameters investigated. Although 15-15-15 has proved most effective in this study, long-term research is needed for confirmation. It is also necessary to evaluate its economic benefits along with other nitrogen sources particularly urea.

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RÉSUMÉ

KWAKYE, P. K. & AFORO, D.: *Comparaison de l'efficacite d'azote applique à l'état pur et à l'état des engrais composés, sur le mais dans utisol de la savane côtière.* L' efficacité de N appliqué comme urée, sulfate d' ammonium et dans les engrais composés 15-15-15 et 20-20-0 à 0, 60 et 120 kg N/ha sur maïs (cv. Abeleehi) était évaluée dans un ultisol de la région centrale du Ghana. Les résultats indiquaient que 15-15-15 était considérablement supérieur aux autres engrais testés à l' égard du rendement culturelle et la consommation de nutritif total par la culture maïs. Le *p*H du sol était considérablement réduit par l'application de sulfate d'ammonium. L' augumentation de la proportion d'azote au-delà de 60 kg/ha n'avait aucun avantage sur les paramètres enquêtés. Malgré le fait que 15-15-15 s'est prouvé le plus efficace dans cette étude, une recherche à long-terme est nécessaire pour une confirmation. Il est également nécessaire d' évaluer ses bien faits économiques à côté d' autres source d' azote, surtout l'urée.

Introduction

Most Ghanaian soils are deficient in total nitrogen. Consequently, the amounts of available forms of this nutrient released during mineralization of soil organic N are usually inadequate to satisfy crops' requirements. The ideal hydrothermal conditions which favour mineralization of organic N at the same time also enhance the loss of N released through leaching, volatilization and immobilization. Nitrogen fertilization has, therefore, been long recognized as necessary for sustained crop production on most soils of Ghana.

The results of early investigations (Nye, 1953; Djokoto & Stephens, 1961; Ofori, 1973; FAO, 1974-76) and recent ones (Kwakye, 1988; Kwakye, Dennis & Asmah, 1995) have shown large responses of different crops to N fertilization in Ghana.

Since the introduction of usage of fertilizers in Ghanaian agriculture, the use of sulphate of ammonia as N source has been on the increase. The increased soil acidity developed through continuous application of this N fertilizer and its attendant reduction of nutrient availability (e.g., phosphorus) and increased availability and toxicity of micronutrients (e.g. Zn, Cu, Fe, Mn) is well documented (Cooke, 1972; Ofori, 1973; Kwakye, Dennis & Asmah, 1995; Roy, Larry & Roy, 1981; Obi, 1976; Jones, 1976; Aduayi, 1980). As a result, more attention is gradually being directed to the use of less acidifying N source such as urea. In 1990, the Ghana Ministry of Agriculture conducted a series of training courses for extension workers throughout the country on the use of urea as N source of fertilizer. This was aimed at intensifying the awareness of the benefits of urea as against the adverse effects of sulphate of ammonia.

Current fertilizer practice for maize is to apply compound fertilizer at planting and topdress with urea or sulphate of ammonia 6 weeks after planting. Sometimes only one source, compound or straight N fertilizer may be available during the entire cropping season.

In a situation, where only compound fertilizers are available, the current practice described above for maize cannot be employed; the total amount of the compound must be applied once because phosphate and potash for the crop are not split. Studies on the agronomic effectiveness of different N sources and the compound fertilizers, and evaluation of their chemical effects on the soil have become necessary to ensure better understanding and the proper use of these materials to prevent environmental/soil degradation. This is important since liming is not practised by Ghanaian farmers. The objective of this study was, therefore, to compare the effectiveness of two sources of straight N and compound fertilizers on maize yield and soil *p*H.

Materials and methods

The experiment was conducted at the School of Agriculture Teaching and Research Farm, University of Cape Coast, Cape Coast in the Central Region of Ghana, during the major rainy season of 1990. The soil at the experimental site is intensively weathered, highly leached of bases, has low cation exchange capacity and is dominated by kaolinite clay and sesquioxides (Asamoa, 1973). According to Asamoa (1973), the soil belongs to the Atabadzi series. It is classified, according to the soil taxonomy, as Ultisol. The site was ploughed to about 23 cm deep and harrowed. Some physical and chemical properties of the top (0 - 23 cm) soil determined by standard analytical methods (Page, Miller & Keeney, 1982) are shown in Table 1.

TABLE 1

Some Physical and Chemical Properties of the Soil (0-23cm)

*p*H (1:1) H_2O	4.8
Per cent organic carbon	1.68
Per cent total nitrogen	0.15
Available P (μg/g) Bray P_1	1.75
Exchangeable cations (In NH_4 OAc. cmol/kg)	
Ca^{2+}	1.6
Mg^{2+}	0.2
K^+	0.1
$Al^{3+} + H^+$	3.15
Particle size distribution (per cent)	
sand	58.1
silt	32.9
clay	8.7

The treatment consisted of two sources of straight N and two sources of N in compound fertilizers at two levels each: 60 and 120 kg/ha N and a control arranged in a randomized complete block design with three replications. At planting, half of the urea and sulphate of ammonia with single superphosphate and muriate of potash equivalent to the P and K contents of the compound fertilizers, and all the compound fertilizers were broadcast and incorporated into the top (10 cm) soil by hoeing.

Abeleehi, a high yielding maize variety, was planted at 75 cm between rows and 30 cm within rows with one seed per hole on 4 May 90. Each plot measured 5 m× 6m. The remaining urea and sulphate of ammonia was side-dressed 6 weeks after planting. At tasselling stage, ten ear leaves were randomly sampled per plot 2 weeks after side-dressing with the remaining N ferilizers. The samples were air-dried for 5 days, oven-dried for 48 hours, and finely ground and sub-sampled for the determination of total N, P and K concentrations using standard analytical methods (Lott, 1956).

At harvest, the whole plants were cut at the ground level and weighed. Cobs were collected from each plant per plot. Plant samples were oven-dried at 65 °C for 48 h for moisture determination to enable conversion of fresh yield data into total dry matter yield. Grains were sampled, oven-dried and finely ground for total N, P and K determination. The per cent nutrient concentrations were used to estimate the total N, P and K uptake in the maize grain. Top soil samples were also collected for *p*H determination.

Results and discussion

Grain yield

The results in Table 2 show that grain yields were below the yield potential (4000 kg/ha) of the variety

TABLE 2

Effect of Nitrogen Fertilization on Grain Yield of Maize (kg/ha)

N source	Rate applied (kg/ha)	Grain yield
Control		2500 a*
Ammonium sulphate	60	2700 abc
Ammonium sulphate	120	2445 a
Urea	60	3220 cde
Urea	120	3240 cde
20-20-20	60	3420 def
20-20-20	120	3065 bed
15-15-15	60	3770 ef
15-15-15	120	3815 f

* Means followed by the same letter within each column are not significantly different at $P = 0.05$.

used in this experiment. At the beginning of the grain filling stage long period of drought persisted in the coastal savanna zone of the Central Region. The poor rainfall and its distribution could have accounted for the low grain yield of maize.

With the exception of sulphate of ammonia, the rest of the fertilizers increased yields significantly (P=0.05).

Application of N at 60 kg N/ha tended to give higher yields than 120 kg N/ha rate although the differences were not significant. The lower yield might be due to increased acidity caused.

The study has proved the compound 15-15-15 to be superior to either sulphate of ammonia or urea supplemented with P and K fertilizers in terms of N uptake and grain yield of maize (Table 3).

TABLE 3

Effect of N Sources on NPK Concentration in Maize Ear Leaf at Tasselling (per cent)

N source	Rate applied (kg/ha)	Percentage		
		N	P	K
Control		1.01e*	1.00d*	2.04bc*
Ammonium sulphate	60	1.68d	0.16c	2.49ab
Ammonium sulphate	120	2.00bc	0.21ab	2.09bc
Urea	60	2.06ab	0.21ab	1.86c
Urea	120	2.04ab	0.22ab	1.95c
20-20-20	60	1.899bc	0.20b	2.21bc
20-20-20	120	2.01bc	0.23ab	2.73a
15-15-15	60	2.18a	0.23ab	2.45abc
15-15-15	120	2.15ab	0.25a	2.26abc

*All means in column followed by the same letter are not significantly different at $P = 0.05$.

Nutrient concentration in maize leaf

At tasselling, all the N. fertilizers significantly increased the N concentration in the maize leaf with increases ranging from 66 to 116 per cent (Table 3). With the exception of sulphate of ammonia, increasing rate of N had no significant effect on the N concentration in the maize leaf. The highest N concentration was obtained with the application of the compound fertilizer, 15-15-15 while the least was obtained with the application of lower rate of sulphate of ammonia.

Except in the case of sulphate of ammonia, each source of N fertilizer significantly increased the absorption and translocation of P into the maize leaf. However, there was no significant increase in the P concentration when the rate of N was doubled, except sulphate of ammonia (Table 3). These results compare with the observations of Kamprath (1987) and Farah & Hatata (1985) that phosphate uptake and translocation are regulated by N. They found that P concentration at silking was increased by N fertilization and was highly correlated with leaf N concentration. The low P concentration in the maize leaf from the control plot which also received phosphate fertilizer might be due to the absence of applied N. Since the *p*H of the two plots treated with sulphate of ammonia were the same, the amount of P absorbed by the maize crop would be expected to be greater from the plots which received 120 kg P_2O_5/ha.

The application of the compound fertilizers did not significantly increase the P concentration in the maize leaf probably to due fixation by the acid soil.

Nutrient uptake

The N content of the grain was significantly influenced by N fertilization (P=0.05). The application of the compound fertilizer 15-15-15 resulted in the highest N uptake which was significantly greater than N uptake from the other treatments (Table 4). The lowest N uptake occurred with the application of 120 kg N/ha as sulphate of ammonia. The P and K uptake followed similar pattern like that of N; the highest uptake was recorded with the application of 15-15-15 while the lowest was obtained by applying sulphate of ammonia. It was observed that the uptake of all three nutrients was not significantly increased by doubling the rate of fertilizer application. These results show some interdependence among the nutrients. Veress (1972) observed that the relative concentration of the macro-elements indirectly influence the uptake of each other. As nitrogen influences uptake of potassium, so does potassium influence phosphorus and phosphorus determines the uptake of nitrogen. Stamboliev & Ignatava (1976) reported that increasing N rates in combination with P and K and increasing P rates in combination with N increases grain content of N and P, but increasing K rates in combination with N, P had no effect. However, in the present study where N, P and K rates were increased in the same ratio, the results indicated no advantage of the higher rate over the lower rate of the fertilizers on the uptake of the three nutrients.

TABLE 4

Effect of Nitrogen Fertilizers on Nutrient Uptake (kg/ha)

N source	*Rate applied (kg/ha)*	*Total nutrient uptake (kg/ha)*		
		N	*P*	*K*
Control		18.18a*	2.5a*	34.3a*
Ammonium sulphate	60	43.5cd	3.0a	37.5a
Ammonium sulphate	120	33.3b	3.2a	34.7a
Urea	60	46.7cd	5.2b	46.7de
Urea	120	40.8bc	5.5b	45.7cd
20-20-20	60	49.2d	6.5c	48.2de
20-20-20	120	48.4d	5.8bc	40.5bc
15-15-15	60	64.5e	7.5d	50.5e
15-15-15	120	61.0e	8.0d	50.4e

*All means in column followed by the same letter are not significantly different at P = 0.05.

TABLE 5

Effect of N Sources on Soil pH

N source	*Rate applied (kg/ha)*	p*H*
Control		4.4 a*
Ammonium sulphate	60	4.0 b
Ammonium sulphate	120	3.9 b
Urea	60	4.2 a
Urea	120	4.3 a
20-20-20	60	4.3a
20-20-20	120	4.2a
15-15-15	60	4.3 a
15-15-15	120	4.3 a

*All means in column followed by the same letter are not significantly different at P = 0.05.

Soil p*H*

The results in Table 5 show that although all the N sources caused a reduction in soil *p*H, only the application of sulphate of ammonia significantly increased soil acidity. The deleterious effect of sulphate of ammonia on soil reaction has been amply documented (Anderson, 1970; Ofori, 1973; Soon & Miller, 1977). Continuous use of sulphate of ammonia has been shown to pose a serious environmental problem through increased soil acidity.

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