Effect of different levels of N/K_2O ratios on the yield and quality of pineapple in forest-savanna ecotone of Ghana

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SUMMARY

A field study was undertaken to investigate the most suitable $N:K_2O$ ratio required to determine the optimum economic fertilizer level for the production of pineapple cv. Smooth Cayenne fruits in the southern forest-savanna ecotone of Ghana. The trial was sited at Pokuase, Parrico and Silwood farms on fields previously fallowed to *Chromolaena odorata* for over two years. Nitrogen at two levels (224 and 336 kg N/ha) were each combined with different levels of K_2O to give $N:K_2O$ ratios of 1:1.5, 1:2 and 1:2.5. All plots received basal application of 50 kg P_2O_5/ha as single superphosphate. Consistent and significant ($P = 0.05$) response of the crop to varying ratios was obtained for ratios with low level of N(224 kg/ha) at all the sites. At high N level, increasing K_2O did not affect the fruit weight at Pokuase but caused a decline at Parrico and Silwood. The $N:K_2O$ ratios at 336kg N/ha led to a significant increase in both acidity and brix contents of the juice. With the exception of N, the concentration of P, K, Ca and Mg in the D-leaf was adequate for the 10-month old plants at both N levels. No significant relationship was observed between the leaf nutrients and the yield and quality parameters. It may be concluded from the study that $N:K_2O$ ratio of 1:2.5 at a low level of 224 kg N/ha seems to be adequate for pineapple cv. Smooth Cayenne in the forest-savanna ecotone of Ghana.

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RÉSUMÉ

OWUSU-BENNOAH, E., NUTSUKPO, D. K., ADU AMANKWA, P. (MRS) & AHENKORAH, Y.: *Effet de différents niveaux de proportions N/K_2O sur le rendement et la qualité d' ananas dans l' écotone forêt-savane du Ghana.* Une étude de terrain a été entreprise pour enquêter la proportion N: K_2O la plus convenable exigée pour déterminer le niveau économique d' engrais pour la production de fruits d'ananas cv. Smooth Cayenne dans l'écotone forêt-savane au sud du Ghana. L' essai a été situé aux champs de Pokuase, Parrico et Silwood sur les terrains précédement laissés en jachère au (*Chromolaena odorata* à pius de deux ans. L' azote à deux niveaux (224 et 336 kg N/ha) étaient chacun combinés avec des différent niveaux de K_2O pour donner les proportions $N:K_2O$ de 1:1.5, 1:2, et 1:2.5. Tous les lotissements ont reçu l'applications basale de 50 kg P_2O_5/ ha comme superphosphate unique. Une réponse logique et significative (P =0.05) de la culture aux proportions variantes a été obtenue pour les proportions avec un niveau faible de N (224 kg/ha) à tous les endroits. Au niveau fort de N, l' aacroissement de K_2O n' avait pas d' effet sur le poids fruitier à Pokuase mais provoquait un déclin à Parrico et Silwood. Les proportions N : K_2O à 336 kg N/ha a mené à un accroissement significatif des contenus d' acidité et de brix du jus à la fois. A l'exception de N, la concentration de P, K, Ca et Mg dans la feuille - D était adéquate pour les plantes à l' âge de 10-mois aux deux niveaux de N. Aucun rapport significatif n' était observé entre les nutritifs du feuillage et les paramètres du rendement et de qualité. De l' étude, la conclusion pourrait être tirée que la proportion 1:2.5 de N: K_2O à un niveau faible de 224 kg N/ha semble être adéquate pour l' ananas cv. Smooth Cayenne dans l' écotone forêt-savane du Ghana.

Introduction

Pineapple (*Ananas comosus* (L.) Merr.) has become one of the most important non-traditional horticultural export crops in Ghana with increasing potential on the export market. The most important growing areas in Ghana are in the southern forest-

savanna ecotone, especially in the Nsawam, Kasoa and Cape Coast districts. The volume of exports of the crop increased more than 60 per cent from about 8,000 tonnes in 1989 to 13,000 tonnes in 1993 (Owusu-Bennoah, 1995). Although the industry is growing at a very fast rate, it is saddled with many problems which result in low yields on farmers' plots. A survey conducted by the National Agricultural Research Project in the zone in 1992, revealed that improper and inadequate plant nutrition constitute one of the serious problems affecting the industry (NARP, 1992). So far, most of the fertilizer studies with pineapple had been carried out in the forest zone of the country. According to Obiefuna, Majumder & Ucheagwu (1987), the response of pineapples to fertilizer application varies with locality, soil and climate. For example, Godfrey-Sam-Aggrey (1970) working with Sugar loaf pineapple found that nutrient combination of 40 kgN/ha, 47 kg P_2O_5/ha and 36 kg K_2O/ha resulted in maximum yield in the forest zone. Abutiate & Eyeson (1973) also working within the same agro-ecological zone with Smooth Cayenne reported high yield and mean fruit weight for nitrogen and potassium. Excessive nitrogen reduced the total soluble solids (TSS) content of the juice while potassium raised it. Other studies in Nigeria (Obiefuna, Majumder & Ucheagwu, 1987) showed significant increases in pineapple yield on ferrallitic soils with the application of 200 kg N/ha, 50 kg P_2O_5/ha and 200 kg K_2O/ha. According to Asoegwu (1987), the pineapple plant requires a well-balanced N/K_2O ratio for normal growth, high yield and good quality fruits. The most desirable N to K_2O ratio of the fertilizer had been established by several workers to be approximately 1:2 (Lacoeuille, 1971; De Geus 1973; Dalldorf, 1975 and Velez-Ramos, Marquez & Chao de Ba'ez, 1991). However, since the soils and ecological zones where pineapples are grown vary greatly in climatic and chemical composition, adherence to a fixed N/K_2O ratio would provide inadequate amounts of nutrients for some soils or entail luxury feeding in other cases.

No previous work has been carried out in the forest-savanna ecotone of Ghana, where the bulk of the crop is produced for export, to determine the optimum N/K_2O ratio for economic production of the crop. This study was, therefore, initiated to investigate the effect of different levels of N/K_2O ratios on fruit weight and quality of pineapple cv. Smooth Cayenne in the forest-savanna ecotone of Ghana.

Materials and methods

Field trials

The field trials were conducted at three locations, Pokuase, Parrico and Silwood, all within the forest-savanna ecotone from March 1992 to November 1993 on land which had previously been under *Chromolaena odorata* fallow over 2 years. Before land clearing, random soil samples were taken to a depth of 15 cm at all three sites. All soil samples were air dried and ground to pass through a 2-mm sieve. The fine earth fraction was used for laboratory analysis.

Pineapple suckers were graded and those weighing approximately 450 g were planted in double rows on the flat, spaced 30 cm × 30 cm × 90 cm. There were 80 plants per plot, giving a plant population of 55 000 plants/ha. Plot size was 6 m × 2.4 m. The treatment consisted of N at two levels (224 and 336 kg N/ha). Each N level was combined with three different levels of K_2O to give two sets of N/K_2O ratios of 1:1.5, 1:2 and 1:2.5. There were, therefore, six different combinations of N/K_2O ratios, replicated three times in a randomized complete block design. Nitrogen source was ammonium sulphate while potassium source was muriate of potash. All plots received a basal dressing of 50 kg P_2O_5/ha as single superphosphate. The nutrients were applied to the axils of the basal leaves in three split doses at 6,16 and 24 weeks respectively, after planting in proportions shown in Table 1.

TABLE 1

Proportion of Nutrients applied at Three Different Times

Nutrients	*6 weeks*	*16 weeks*	*24 weeks*
Nitrogen	2	3	1
Phosphorus	1	0	0
Potassium	1	2	3

The pineapple leaf samples were collected at 10 months after planting (MAP). D-leaf samples from five plants per plot were randomly taken and analysed for the N, P, K, Ca, and Mg contents. Plants were induced 11 MAP with a saturated solution of calcium carbide. There was a repeat application of inductant three days after the first. Fruits were harvested at the one-third stage of ripening. From a 10 per cent random sample the mean fruit yield per plot and quality parameters (total soluble solids and acidity) were determined as described by Pearson (1970).

Laboratory soil analyses

Particle size distribution was determined by the hydrometer method after dispersion of the soils with sodium hexametaphosphate. Soil *p*H was measured in 1:2.5 (w/v) of soil: water and in 1:2 (w/v) soil: 0.1M $CaCl_2$ suspension. Organic carbon was determined by the Walkley-Black method (Walkley & Black, 1934). Exchangeable bases (Ca, Mg, K and Na) were extracted with 1 M ammonium acetate solution at *p*H 7.0 (Thomas, 1982). Potassium and sodium in the solution were determined using flame photometry while concentrations of Ca and Mg were determined by titration with 0.02N EDTA (Moss, 1961). Total N was determined by semi-micro Kjeldahl procedure (Bremner, 1965). Available P values of the soils were determined by extraction with 0.5M $NaHCO_3$ (*p*H 8.5) and the P concentration measured by the molybdate blue method as described by Watanabe & Olsen (1965).

Results and discussion

Table 2 gives the mean rainfall and temperature data of the sites during the experimental period. Mean rainfall value was lower at Pokuase than at Parrico and Silwood. The temperature at Parrico was generally lower than at the other two sites. The soils at Pokuase, Parrico and Silwood farms are classified as Bawjiasi, Beraku and Sutawa series (local classification) or as Haplic Lixisols, Dystric Regosols and Dystric Cambisols respectively, under FAO system (Adu & Asiama, 1992). Some selected physico-chemical characteristics of the soils of the three experimental sites are presented in Table 3. The soils were loamy sand in texture, slightly acidic, low in organic carbon and total nitrogen. The exchangeable K of the sites was less than 0.35 cmol(+) kg^{-1}. This value was lower than what Magistad (1934) and Su (1958-59) recorded as the threshold for lack of response to K addition. Generally, the available P of the soils at the sites was equally low. Table 4 shows the results of the effect of N and K_2O ratios on fruit yield, acidity and

TABLE 2

Rainfall and Temperature Values for the Sites during the Growing Period

Sites	*Rainfall (mm)*		*Temperature (°C)*	
	Total	*Mean*	*Min.*	*Max.*
Pokuase	1152	66	21-23	30-33
Parrico	1839	105	19-21	27-29
Silwood	1719	101	20-22	30-32

Source: Meteorological Department, Accra.

TABLE 3

Some Physical and Chemical Properties of the Soils from the Three Sites

Soil properties	*Sites*		
	Pokuase	*Parrico*	*Silwood*
Per cent sand	81.0	79.5	79.9
Per cent silt	7.8	7.9	6.9
Per cent clay	11.2	12.6	13.1
*p*H 1 : 2.5 Soil : Water	6.4	6.4	5.4
1 : 2 Soil : 0.01*M* $CaCl_2$	5.7	5.9	5.1
Per cent total organic carbon	0.6	0.8	0.6
Per cent total N	0.06	0.1	0.1
Exchangeable cations cmolkg^{-1}			
Ca	4.35	7.54	7.24
Mg	2.47	3.65	3.42
K	0.23	0.35	0.32
Na	0.10	0.13	0.11
Available P (mgkg^{-1})	5.80	7.85	5.98

TABLE 4

Effect of N and K_2O Ratios on Fruit Yield (tonnes/ha), Acidity and Total Soluble Solids

Treatment				*Sites*													
				Pokuase					*Parrico*					*Silwood*				
N (kg/ha)	*K_2O (kg/ha)*	*N*	*K_2O*	*Yield (t/ha)*	*MFW* (kg)*	*Acid (per cent)*	*TSS*	*TSS/ AC*	*Yield (t/ha)*	*MFW (kg)*	*Acid (per cent)*	*TSS*	*TSS/ AC*	*Yield (t/ha)*	*MFW (kg)*	*Acid (per cent)*	*TSS*	*TSS/*
224	336	1	1.5	77.0	1.4	0.69	18.4	26.6	148.5	2.7	0.66	18.1	27.4	137.5	2.5	0.71	17.2	24.2
224	448	1	2.0	82.5	1.5	0.66	19.2	29.0	154.0	2.8	0.82	19.1	23.3	148.5	2.7	0.80	17.7	22.1
224	560	1	2.5	93.5	1.7	0.59	17.4	29.5	165.0	3.0	0.68	18.1	26.6	159.5	2.9	0.79	18.5	23.4
336	504	1	1.5	77.0	1.4	0.55	17.0	30.9	148.5	2.7	0.73	17.3	23.7	154.5	2.8	0.71	17.2	24.2
336	672	1	2.0	82.5	1.5	0.63	18.6	29.5	143.0	2.6	0.80	17.7	22.1	137.5	2.5	0.79	17.9	22.7
336	840	1	2.5	82.5	1.5	0.67	18.4	27.5	132.0	2.4	0.98	19.0	19.4	132.0	2.4	0.89	18.1	20.3
Mean				82.5	1.5	0.63	18.2	28.8	148.5	2.8	0.79	18.2	24.3	144.8	2.7	0.80	17.8	22.9
LSD at $P = 0.05$				3.9	0.2	0.06	1.0	2.9	1.7	0.3	0.05	NS	7.1	1.5	NS	0.1	NS	3.0
CV (per cent)				2.7	12.2	10.6	4.8	8.8	0.6	8.3	22.9	8.9	20.7	0.6	17.4	9.3	7.5	9.2

*MFW = Mean Fresh Weight AC = Acidity TSS = Total Soluble Solids

total soluble solids. At all the experimental sites there was a consistent increase in the yield and fruit weight with varying levels of N:K_2O ratios at the low level of N (22kg N/ha). A similar trend of response was reported by Su (1969), Abutiate & Eyeson (1973) and Tay (1974) using the Smooth Cayenne cultivar. At higher N level (336 kg N/ha), however, increasing K_2O levels did not affect the fruit weight at Parrico and Silwood. This is contrary to the finding of Obiefuna, Majumder & Ucheagwu (1987) who observed that high N combined with high K_2O produced high fruit yield. Field observation at Parrico and Silwood showed that piots receiving the high dosage of N coupled with high rainfall at the sites produced high vegetative growth and this might have accounted for the decline in yield and fruit weight observed. As shown in Table 4, the application of 224 kg N/ha and 560 kg K_2O/ha produced the highest yield and fruit weight at all experimental sites.

Generally, the fruits from Pokuase were 40-49 per cent smaller than those obtained from Parrico and Silwood (Table 4). This could be attributed to the low rainfall experienced at the former site. Except for Pokuase, fruits from Parrico and Silwood did not qualify for the fresh fruit market as stated by Protrade (1994) who gave the range of 0.9-1.5 kg for the fresh fruit on the international market.

The per cent total soluble solids and citric acid as affected by the N-K_2O ratios are shown in Table 4. According to Tay, Wee & Chong (1968) the quality of pineapple fruit is expressed in terms of total soluble solids, largely sugars and acid contents. These parameters did not show any clear trend at low N level at all the experimental sites. However, there was the tendency, particularly, for the acid content of the juice to increase at the high N level with increasing K_2O application. Similar results have been obtained by Tay (1974). As shown in Table 4, the quality values obtained in the present study were generally higher than those reported by Reusse (1968) and Abutiate & Eyeson (1973) for a similar cultivar in Ghana but fell within the acceptable range for the export market (COLEACP, 1993). Abutiate & Eyeson (1973) attributed the low quality values to over-ripeness and the delay in fruit analysis. In the present experiment, the fruits were analysed at the early mature stage and this might have accounted for the high acid contents of the fruits. The mean Brix:

acidity ratio generally ranged from 23.0 to 29.0 at the varying N:K_2O ratios. However, at Parrico and Silwood a lower ratio ranging from 19-22 was obtained. According to Tay (1973) quoting Meleindez of the Lotus pineapple processing plant, Barceloneta a Brix: acidity ratio from 24 to 30 is an indication of good pineapple fruit quality for the Red Spanish cultivar.

Table 5 shows D-leaf composition of per cent N, P, K, Ca and Mg. Even though D-leaf nutrient content may vary with age, climate and variety, the generally accepted adequate values on a dry weight basis are as follows:

N = 1.5 - 1.7 per cent, P = 0.08 - 0.23 per cent, K = 0.8 - 4.2 per cent, Ca = 0.025 - 0.3 per cent and Mg = 0.20 - 0.25 per cent (Dalldorf & Langenegger, 1978 Angles, Sumer & Babour, 1990). The major nutrients P,K, Ca and Mg contents of 10 month-old plants were adequate, except for N, which was low (< 1.08 per cent). Even though the values of the K/N ratio in D-leaf fell below the critical values of 2.7 reported by Nightingle (1942) and 3.0 by Martin-Prevel (1959), it did not adversely affect the quality of the fruits as shown in Table 4.

In the case of K/P ratio, while the values for Pokuase fell below the ideal figure of 14 (Lacoeuille, 1971) those of Parrico and Silwood were higher (range 17-21). No relationships were observed

TABLE 5

Effect of N and K_2O on D-Leaf Nutrient Levels at 10 Months after Planting

N	*K_2O*	*N:K_2O*	*N*	*P*	*K*	*Ca*	*Mg*	*K/N*	*K/P*
	(kg/ha)				*(per cent)*				
Pokuase									
224	336	1:1.5	0.7	0.2	1.4	0.2	0.2	2.0	6.8
224	448	1:2.0	0.8	0.1	1.5	0.2	0.2	2.0	12.5
224	560	1:2.5	0.7	0.2	1.4	0.2	0.2	2.0	9.7
336	504	1:1.5	0.8	0.2	1.4	0.2	0.2	1.9	9.7
336	672	1:2.0	0.8	0.1	1.4	0.2	0.2	2.0	12.0
336	840	1:2.5	0.9	0.2	1.6	0.2	0.2	1.8	10.3
Parrico									
224	336	1:1.5	0.7	0.1	1.8	0.3	0.3	2.6	17.5
224	448	1:2.0	0.8	0.1	1.9	0.3	0.3	2.6	19.0
224	560	1:2.5	0.8	0.1	1.9	0.2	0.2	2.3	18.5
336	504	1:1.5	1.0	0.1	1.9	0.2	0.2	1.9	18.5
336	672	1:2.0	0.8	0.1	1.9	0.3	0.3	2.6	19.0
336	840	1:2.5	1.0	0.2	2.0	0.2	0.2	2.0	19.5
Silwood									
224	336	1:1.5	0.7	0.1	1.8	0.3	0.2	2.6	20.7
224	448	1:2.0	0.8	0.1	1.9	0.3	0.2	2.5	20.6
224	560	1:2.5	1.2	0.1	1.9	0.3	0.2	1.5	20.2
336	504	1:1.5	1.3	0.1	1.8	0.3	0.2	1.5	20.3
336	672	1:2.0	1.1	0.1	1.9	0.3	0.2	1.5	21.0
336	840	1:2.5	1.4	0.1	1.9	0.3	0.3	1.4	20.0

between leaf N, P, K at 10 months after planting and mean fruit weight and quality parameters. Generally, the combined effect of N: K_2O ratio (224kg N/ha and 560kg K_2O/ha) (Table 3), gave the desired qualities which fell within the acceptance quality range for fresh fruit export (Protrade, 1994).

It may be concluded from the study that the ratio 1:2.5, i.e. 224kg N/ha and 560 kg K_2O/ha seems to be adequate for pineapple cv. Smooth Cayenne in the southern forest-savanna ecotone of Ghana. it is however, suggested that further studies should be initiated particularly, in the other equally important pineapple growing areas of the zone such as Kasoa and Obom districts to confirm the present findings.

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