The response of pineapple (*Ananas comosus* L.) Merr. var. Smooth Cayenne to nitrogen, phosphorus and potassium in the forest zone of Ghana

W. S. ABUTIATE & K. K. EYESON

(*W.S.A.: Crops Research Institute, P.O. Box 3785, Kumasi, Ghana: K.K.E.: Food Research Institute, P.O. Box M.20, Accra, Ghana*)

SUMMARY

The response to NPK fertilizer is presented for the plant crop of Smooth Cayenne pineapple. N and K addition resulted in significant increase in yield and mean fruit weight. P had a depressing effect on yield but its effect on mean fruit weight was inconsistent. N addition significantly reduced the total soluble solids content of the juice while K raised it. There was a significant N × P interaction on the acid content of the juice.

Provisional communication. Received 15 Aug 72; revised 10 May 73.

RÉSUMÉ

ABUTIATE, W. S. & EYESON, K. K.: *Réaction aux engrais azotés, phosphorés et potassiques des ananas* (Ananas comosus *L.) Merr. de la variété lisse de Cayenne, dans la zône forestière du Ghana.* Les auteurs ont étudié l'action des engrais à base de N, P et K sur la récolte de la variété lisse de Cayenne d'ananas. L'application de N et K a produit une augmentation notable de la récolte et du poids moyen des fruits. L'application de P a provoqué une diminution de la récolte, mais n'a eu aucun effet sur le poids moyen des fruits. L'application de N a réduit nettement l'extrait sec total du just des fruits, tandis que l'application de K l'a augmenté. L'acidité du jus des fruits a été influencée par une nette interaction de N et de P.

Introduction

Pineapple cultivation by peasant farmers in Ghana dates from the 1930's when there was already a flourishing local trade in the Central Region. The production at the time was solely for home consumption, but later developed and reached its peak in 1960 when the need for commercial cultivation was felt after the establishment of a cannery.

Pineapple grows in almost all the ecological zones of the country, but by far the greatest concentration of farms is found in the Nsawam and Cape Coast districts. Aborobeanu, Kafodzidzi and Kwasi Kwaa in the Elmina district, Sachikrom and Ntoase in the Nsawam district were mentioned by Godfrey-Sam-Aggrey (1969) as the focal points of cultivation. Areas of recent commercial production include Samsam and Achiase.

Pineapple yields are low in Ghana. Among the reasons for these low yields are improper spacing, lack of weed and pest control and complete lack of fertilization. With the increased demand for fruits for the cannery and for export, it is evident that greater attention will need to be paid to its cultivation if increased yields are to be realized to cope with demand.

The importance of a proper fertilizer programme for optimum pineapple growth and production has been amply demonstrated by numerous workers (Cannon, 1957; Su & Yow, 1958–59; Sideris & Young, 1960; Tay, Wee & Chong, 1968; Jorgensen & Page, 1969). Nightingale (1942) showed that N was the most limiting nutrient in pineapple cultivation. As the N status of Ghana soils is generally low except in the forest areas, it will be expected that this nutrient will play a major role in the production of pineapple, especially in the savanna area.

A fertilizer trial on Smooth Cayenne pineapple was laid out in 1969 with a view of finding the response to the various NPK levels under the forest zone conditions. The preliminary findings are presented in this paper.

Materials and methods

A 3^3 fractional trial in randomized block with four replications was laid out on a previously fertilized replant site at the Central Agricultural Experiment Station at Kwadaso. The test site was a mature secondary forest. It was first cleared in 1967 and cropped to pineapple for 2 years. Before planting, soil samples, taken from 0–15 cm, were analysed for *p*H, available P by Bray's P_1 method (Bray & Kurtz, 1945), K and organic matter (Table 1).

Suckers were graded and those with similar size were planted in the same block to obtain intra-block uniformity. A single row planting system was adopted owing to scarcity of planting material. Plants were spaced 30 cm within rows, 152 cm apart, giving a plant population of 21 780 plants per hectare. Each replicate was completely guarded by a single row of planting. Suckers were planted in the field on 12 Sep 69. Plot size was 3·0 m × 1·5 m.

The fertilizer treatments are summarized in Table 2. All fertilizers were applied in three equal schedules. The first application was made a day before planting on 11 Sep 69 and the remaining two, on 12 Mar 70 and 13 Aug 70, 6 and 11 months respectively after planting. Plants were allowed to flower spontaneously.

Fruits were considered ripe and ready for harvest when three to four eyes were coloured. Weekly harvesting was started in October 1970 and was completed in April 1971. Weights of fruits without tops were recorded at each harvest. In all, 20% of fruits in each treatment were analysed.

Juice from whole fruits was extracted within 2 days after harvest by means of a Toshiba multi-press centrifugal juice extractor and used for the determination of total soluble solids and acidity. The methods of analysis were those outlined by Pearson (1970). Acidity was expressed as percentage of anhydrous citric acid.

TABLE 1
Chemical Analysis of Soil

Depth (cm)	*pH*	*% O.M.*	*Available P (ppm P)*	*Exchangeable K m.e/100g soil*
0–15	5·8	3·8	28·0	0·3

TABLE 2
Rates of Fertilizer Application (kg/ha)

Element	*Levels*		
	0	*1*	*2*
N (Ammonium sulphate 21% N)	0	112	224
P (Single superphosphate 18% P_2O_5)	0	56	112
K (Potassium sulphate 50% K_2O)	0	224	448

Results and discussion

Mean fruit yields are shown in Table 3, mean fruit weight in Table 4 and analysis of variance in Table 5.

Nitrogen

Effect on yield and mean fruit weight. Nitrogen application resulted in significant increases in total fruit yield and mean fruit weight (Table 4) There was greater response to the low than to the high level of N applied. This level of N seemed adequate for the plants thus making the extra amount given largely unnecessary as it gave no further significant yield increase. Field observations showed that plots receiving the high dose of N produced more vegetative growth resulting in slightly lower fruitage and relatively higher number of hold-over plants.

Nightingale (1942) showed that N was by far the most limiting nutrient in pineapple cultivation. The results of this preliminary experiment have shown that even with the relatively high amount of organic matter in the soil, some amount of mineral N may be needed in the cultivation of this crop. It would also appear that on soils of similar initial fertility, the N requirements for pineapple might not exceed 112 kg per hectare.

Dodson (1968), Su & Yow (1958–59) and Jacob & Vexkiill (1960) similarly noted yield responses to N addition. Tay *et al.* (1968), however, failed to obtain significant yield increases to added N. None of the NP, NK and NPK interactions was significant.

TABLE 3

Effect of N and P Application on Mean Yields of Pineapple (t/ha)

N (kg/ha)	*K_2O (kg/ha)*			*Mean*
	0	*224*	*448*	
0 ..	21·2	24·3	29·7	25·1
112 ..	24·7	34·0	37·0	31·9
224 ..	34·2	34·2	38·8	37·7
Mean ..	26·7	30·8	35·2	

SE: N = 1·43, K_2O = 1·43, N × K_20 = 2·33

TABLE 4

Effect of N and P Application on Mean Fruit Weight (kg)

N(kg/ha)	*K_2O (kg/ha)*			*Mean*
	0	*224*	*448*	
0 ..	1·7	1·9	2·1	1·9
112 ..	1·8	2·2	2·3	2·1
224 ..	1·9	2·3	2·5	2·3
Mean ..	1·8	2·1	2·3	

SE: N = 0·05, K_2O = 0·05, N × K_2O = 0·09

TABLE 5

Analysis of Variance of Yield and Mean Fruit Weight

Source	*Df*	*MS value*	
		Yield	*Mean fruit weight*
Reps ..	3	4·17	0·22
N	2	207·63**	1·06*
P	2	14·91 NS	0·14 NS
K	2	155·50**	2·07*
Error ..	78	15·72	0·30

* and ** denote significance at P = 0·05 and P = 0·01 respectively; NS = Not significant.

Effect on fruit quality. The per cent total soluble solids and citric acid are shown in Tables 6 and 7 respectively. The analysis of variance is presented in Table 8.

TABLE 6

Effect of N and P Application on Total Soluble Solids (%)

N (kg/ha)	*K_2O (kg/ha)*			*Mean*
		224	*448*	
0 ..	12·7	13·6	14·3	13·5
112 ..	11·8	13·6	13·7	13·0
224 ..	11·9	12·4	13·4	12·6
Mean ..	12·1	13·2	13·8	

SE: N = 0·22, K_2O = 0·22, N × K_2O = 0·37

TABLE 7

Effect of N and P Application on Citric Acid (%)

N (kg/ha)	*P_2O_5 (kg/ha)*			*Mean*
	0	*56*	*112*	
0 ..	0·52	0·50	0·41	0·48
112 ..	0·42	0·49	0·41	0·44
224 ..	0·42	0·37	0·42	0·40
Mean ..	0·45	0·45	0·41	

SE: N = 0·02, K_2O = 0·02, N × K_2O_5 = 0·03

TABLE 8

Analysis of Variance of Total Soluble Solids and Acidity

Source	*Df*	*MS value*	
		Total soluble solids	*Acidity*
Reps ..	3	11·93	0·13
N	2	8·45**	0·05**
P	2	4·60 NS	0·02 NS
K	2	27·91**	0·22**
NP	4	0·23	0·03
Error ..	78	1·69	0·008

**P = 0·01

Tay *et al.* (1968) have stated that quality of pineapple fruit is expressed in terms of total soluble solids, largely sugars and acid contents. Su (1957) observed that N did not alter the sugar content of pineapple fruits. He, however, noted that with the Selengor Green variety, additions of N increased acidity. Cannon (1957) observed that N tended to decrease both sugar and acid. In this experiment, N addition significantly reduced the total soluble solids content of the juice and N $\times$ P interaction was significant for juice acidity (Table 8).

It was found that at the low level of P, increasing the N level resulted in the lowering of juice acidity but at the high level of P, juice acidity increased, though not significantly, with increased N dosage. Juice acidity was low on the whole (Table 7). A similar low value was reported by Reusse (1968) who analysed a random of Smooth Cayenne pineapple grown in Ghana. The sample analysed contained 0·42% anhydrous citric acid and total soluble solids content of 15·8%. Reusse (1968) attributed this low acid content of the juice to overripeness, wrong culling and packing.

In the present experiment, even though efforts were made to harvest fruits at the correct stage of ripeness, some of the fruits were clearly overripe at the time of harvest. Moreover, fruits were usually analysed 2 or 3 days after harvest. Such conditions might have contributed to the low acidity in the expressed juice. As stated by Samuels (1970), however, the Smooth Cayenne group of pineapple is only mildly acid. It seems advisable, therefore, as suggested by Reusse (1968) that in order to determine the most appropriate time for harvesting the Smooth Cayenne pineapple in Ghana, fruits must be analysed at the early mature, mature and late mature stages to determine the most suitable range of acidity commensurate with the best flavour. For, as stated by Su (1958–59), pineapple flavour may be improved through adjustment of acidity. The results of this experiment revealed no relationship between fruit quality and mean fruit weight or yield. None of the NK, PK and NPK interactions also had any significant effect on fruit quality.

Phosphorus

Effect on yield and mean fruit weight. Generally, yields decreased with increasing dosages of P applied. Phosphorus application did not significantly improve mean fruit weight although it increased it slightly at the 56 kg/ha level. The results of site soil analysis showed a very high initial level of available P (Table 1).

It seems probable that this initial level of this nutrient in the soil was adequate and further additions only depressed yield. This view is strengthened by the work of Marchal (1971) who observed that, on P deficient soils, the addition of 1·88 g P per plant was more beneficial than 3·75 g P per plant. Similar depressed yields of pineapple with P additions were recorded by Samuels & Gondia-Diaz (1960) and Briant & Tidbury (1942).

Effect on fruit quality. Phosphorus addition did not have any significant effect on total soluble solids content and acidity of the juice (Table 8). The significant NP interaction on fruit quality, however, clearly calls for further investigations into the combined effect of N $\times$ P on pineapple quality.

Potassium

Effect on yield and mean fruit weight. Potassium application resulted in significant increases in total fruit and mean fruit weight (Table 5). As observed also by Tay *et al.* (1958), the yield response to added K was the most marked of the three elements investigated. Similar yield responses to K have been recorded by Cannon (1957) and Su (1958). Kwong, Chiu & Li (1966) noted that when the soil exchangeable K was already high, further K additions lowered yield. Based upon the results of his investigation, Magistad (1934) concluded that where the exchangeable K level in the soil exceeded 0·5 m.e.% K, soil response to added K would not occur. Su (1958–59) also found that where exchangeable K in the soil contained 4·1 to 5·1 m.e.% K or higher, there was lack of response to further additions of K.

The soil analysis of the test site (Table 1) revealed a relatively high level of exchangeable K in the soil. Even though the observed value of 0·3 m.e.% K was lower than what Magistad (1934) and Su (1958–59) recorded as the threshold for lack of response to K addition, it was, nevertheless, considered high for a Ghanaian soil. This assertion is based upon the general lack of response shown by many crops to this element and the observation that most of the Ghanaian soils are well buffered against K depletion (Ahenkorah, 1970). The results of this investigation have shown that further experiments are needed to establish the upper limit of response to additions of K in the forest zone soils. Lack of response to K has, however, been recorded by Samuels & Gondia-Diaz (1960). Briant & Tidbury (1942) also recorded decreased yields of pineapple to the application of sulphate of potash in Zanzibar.

Effect on quality. Potassium significantly increased the total soluble solids and acid content of the juice (Table 8). Similar observations have been made by Tay *et al.* (1968). Su (1958–59) observed that the total soluble solids content of the juice was not always significantly affected by K additions to the soil.

The results of this investigation have clearly shown that N and K play a major role in determining pineapple yields and quality.

Acknowledgements

The authors are grateful to Dr C. S. Ofori of the Soil Research Institute for his constructive criticism during the preparation of the manuscript. The help of Dr W. K. G. Erbynn with the statistical computation, members of the staff of the Horticultural Section of the Crops Research Institute and the Technical staff of the Food Research Institute in carrying out the routine field work and laboratory analysis respectively is gratefully appreciated. This paper is published with the kind permission of the Director of the Crops Research Institute.

REFERENCES

Ahenkorah, Yaw (1970) Potassium-supplying power of soils of Ghana cropped to cacao. *Soil Sci.* **109,** 127–135.

Bray, R. H. & **Kurtz, L. T.** (1945) Determination of total organic and available forms of P in soils. *Soil Sci.* **59,** 39–45.

Briant, A. K. & **Tidbury, G. E.** (1942) Pineapple experiments in Zanzibar. *E. Afr. agric. J.* **8,** 80–84.

Cannon, R. C. (1957) Pineapple fertilizer investigations in South-Eastern Queensland. *Qd J. agric. Sci.* **14,** 93.

Dodson, P. G. C. (1968) Effects of spacing, nitrogen and hormone treatment on pineapple in Swaziland. *Exp. Agric.* **4,** 103–115.

Godfrey-Sam-Aggrey, W. (1969) Pineapple culture in Ghana. *Wld Crops* **21,** 33–36.

Jacob, A. & **Vexkiill, H. von** (1960) *Fertilizer-use. Nutrition and manuring of tropical crops*, pp. 391–404. Hannover: Verlagsgesellschaft für Ackerbau mbH.

Jorgensen, K. R. & **Page, P. E.** (1969) Comparison of four fertilizer schedules for pineapples in Central Queensland. *Qd J. agric. Sci.* **26,** 495–511.

Kwong, K. H., Chiu, Y. M. & **Li, S. K.** (1966) Field experiments on nitrogen requirement of pineapple in Taitung District. *Soils Fertil. Taiwan*, 88–89.

Magistad, O. C. (1934) Relation between replaceable potassium and field response to potash in Hawaiian soils. *Soil Sci.* **37,** 99–103.

Marchal, J. (1971) Phosphorus in pineapple. *Fruits d'outre mer.* **26,** 189–206.

Nightingale, G. T. (1942) Potassium and phosphate nutrition of pineapple in relation to nitrate and carbohydrate reserves. *Bot. Gaz.* **104,** 191.

Pearson, D. (1970) *The chemical analysis of foods*, 6th ed. London: J. & A. Churchill.

Reusse, E. (1968) Ghana's food industries—An economic analysis. UNDP Report. *EA:SF/GHA/68*, 98–101.

Samuels, G. (1970) Pineapple cultivars 1970. *Fla St. hort. Soc. Q.* **83,** 325–332.

Samuels, G. & **Gondia-Diaz, H.** (1960) A comparison of the yield and nutritional requirements of the Red Spanish and Smooth Cayenne pineapples. *Proc. Caribb. Reg. Am. Soc. hort. Sci.* **4,** 91.

Sideris, C. P. & **Young, H. Y.** (1950) Growth of *Ananas comosus* at different levels of mineral nutrition under greenhouse and field conditions. I. Plant and fruit weights and absorption of nitrate and potassium at different growth intervals. *Pl. Physiol.* **25,** 594–616.

Su, N. R. (1957) An experiment on the nitrogen requirement of pineapples. *J. agric. Ass. China.* **13,** 18–44.

Su, N. R. (1958) The response of pineapples to the application of potassium chloride. *J. agric. Ass. China.* **22,** 27–49.

Su, N. R. (1958–59) Response of pineapple to potash in Taiwan. *Soils Fertil. Taiwan,* 29–38.

Su, N. R. & **Yow, Y. L.** (1958–59) Responses of pineapple to nitrogen, phosphorus and potassium fertilizers. II. Ratoon crop. *Soils Fertil. Taiwan,* 91.

Tay, F. H., Wee, W. Y. & **Chong, W. S.** (1968) The nutritional requirements of pineapples (*Ananas comosus L.*) Merr. var. Singapore Spanish on peat soil in Malaya. *Malay. agric. J.* **46,** 468.