Amounts of NPK removed from soil in harvested coffee berries as guiding baseline for planning fertilizer requirements of coffee in Ghana

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ABSTRACT

Monthly samples of ripened improved robusta coffee berries from compact and large growth forms from three locations, which are representative of the main ecological zones where coffee is grown in Ghana, were taken for 3 years. The pulp and parchment and beans were analysed for N, P and K contents. The amounts of N, P and K removed from the soil in the harvested coffee berries were estimated from the concentrations of the nutrients in the pulp and parchment and beans, and the yield of coffee at each location. The mean NPK contents of the berries were 2.18, 0.08, 2.56 and 2.07, 0.08, 2.52 per cent for compact and large growth forms, respectively. The N and P concentrations in the pulp and parchment were lower than in the bean, while the K content was higher in the pulp and parchment than in the bean across the locations. The N, P and K concentrations of the coffee berries were not significantly different among the growth forms. Coffee berries from suitable and moderately suitable sites removed significantly ($P<0.05$) higher amounts of N and K than the berries from the marginally suitable site, while the P contents of the berries were significantly ($P<0.05$) lower than N and K across the locations. Regardless of the coffee growth forms, the demand for N and K may be higher than P. A fertilizer rate of 30 kg N, 1 kg P, and 33 kg K ha^{-1} may serve as a basis for planning fertilizer requirements of mature coffee in Ghana.

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Introduction

Coffee is an important cash crop in Ghana. Breeding programmes on coffee in Ghana now include the selection of improved clones for high yielding and better adaptability in different environments. However, the nutrient requirements of the clones are unknown and information on the effects of fertilizers on coffee yield in Ghana is inadequate.

Soil and weather factors usually complicate the results of field fertilizer trials, and the results often do not show until after the third year of applying fertilizer (Fennah & Murray, 1958). This suggests that many years of field experimentations are, therefore, required to produce conclusive recommendations. Assuming 1345 coffee trees ha^{-1}, Mehlich (1972) through analysis of ripe coffee fruits, reported 11.6 kg N, 9.0 kg P, and 13.7 kg K ha^{-1} as the amounts of nutrients required by the crop between the second and third year after planting. Krishna & Iyenger (1975) reported that the proportion of nutrients removed by coffee berries, as against the total nutrients in the whole plant, was 57, 64 and 60 per cent N, P_2O_5 and K_2O respectively; and concluded that the nutrients required for producing 1000 kg clean coffee over a unit area of Arabica coffee is 70 kg N, 5 kg P, and 71 kg K. Jan G. de Gues (1973) also stated from available reports that an amount of 35 kg N, 3 kg P, and 42 kg K would compensate for the removal by a yield of 1000 kg market coffee. Malvolta (1990) reported 17.8 kg N, 3.2 kg P, and 38.0 kg K as the amounts of nutrients recycled through pulp and parchment of Arabica coffee per hectare per year in Brasil. The above information point to the need to use the analyses of the constituent parts of coffee, particularly the berries, to supplement field fertilizer trials for estimating the nutritional requirements of coffee.

Information on the effects of growth forms of coffee on some growth characteristics in Ghana indicate higher mean values of girth, length of laterals, diameter of lateral branches, and bean weight for large growth forms compared to compact growth forms (Anim-Kwapong, 2000). The findings suggest that coffee with large growth forms may have higher nutrient requirements than the compact forms. Studies are ongoing on the fertilizer requirements of coffee at the Cocoa Research Institute of Ghana.

This paper reports on the estimate of the amounts of N, P and K removed from soil in the harvested improved robusta coffee berries as guiding baseline for planning the fertilizer requirements of improved robusta coffee clones in Ghana.

Materials and methods

The study was part of a trial started in 1996 to assess the yield performance of some improved robusta coffee clones in the main ecological zones where coffee is grown in Ghana.

Experimental sites

Three locations, namely Tafo, Fumso and Bechem, which fall within different ecological zones where coffee is grown in Ghana, were selected for the trial.

The areas could be described as suitable (Tafo), moderately suitable (Fumso), and marginally suitable (Bechem) in rainfall availability and soil factors. The soils at Tafo, Fumso and Bechem are classified as Rhodi-lixic ferralsol (WRB, 1988) developed over hornblende granodiorite. Table 1a presents some properties of the soils at the beginning of the experiment. The *p*H of soil was determined on 1:2.5 soil to water ratio by glass electrode method. Other chemical analyses were organic carbon (Tinsley, 1950), total nitrogen by the Kjeldahl digestion method (Bremner, 1965), available phosphorus by the method of Truog (1930), and exchangeable potassium after extracting it with 1M ammonium acetate solution on Varian Atomic Absorption Spectrophotometer.

Table 1b presents the average total rainfall during flowering and fruit setting period over

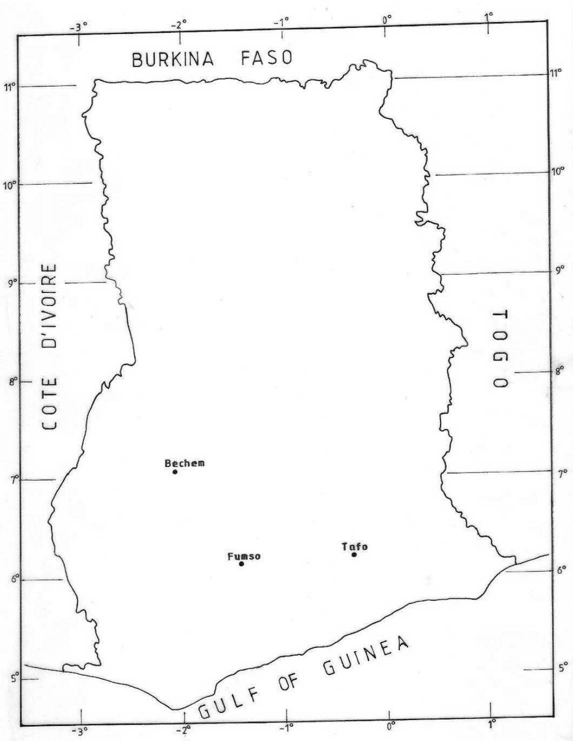

Fig. 1. Map of Ghana showing the experimental sites.

TABLE 1a

Some Chemical Properties of Soil at the Study Sites

Soil property	*Location*		
	Tafo	*Fumso*	*Bechem*
*p*H (1:2.5 H_2O)	7.04	5.99	6.12
Organic carbon (%)	1.93	1.21	1.35
Total N (%)	0.32	0.18	0.10
Available P (mg kg^{-1})	36.9	8.6	9.9
Exchangeable K ($cmol^{(+)}$ kg^{-1})	5.8	4.5	4.7

TABLE 1b

Total Rainfall (mm) During Flowering and Fruit Setting Period (Nov-Mar)

Location	*Amount of rain (mm)**
Tafo	817.4
Fumso	722.8
Bechem	568.7

* Average of 3 years. Source of data: CRIG Progress Report (1999-2001)

3 years at each of the locations.

Coffee clones

In the original experiment, 18 improved robusta coffee clones, comprising compact and large growth forms planted at 2 m × 3 m apart in a randomized complete block design, were used. Five clones of each of the compact and large growth forms were selected from the 18 clones for this study. Compact and large growth forms were differentiated by the lengths of the internodes of their laterals.

Plant sampling and analysis

Monthly samples of harvested coffee berries were taken from each location from September to December each year from 1999 to 2001. Sub-samples of the harvested coffee berries for each period were bulked together, sun-dried, and pulp and parchment separated from the beans and further dried to constant weights.

The pulp and parchment and beans were separately ground and analysed for N, P and K. The plant materials were digested in a ternary mixture of sulphuric acid, nitric acid, and perchloric acid. Nitrogen in the extracts was determined by the Kjeldahl distillation (Bremner, 1965), phosphorus by the molybdenum blue method as described by Homer & Parker (1961), and potassium on the Varian Atomic Absorption Spectrophotometer.

Calculations

The percentage weights of N, P and K in oven-dry materials were calculated from the analysis. The quantities of nutrients removed from the soil in a given quantity of harvested coffee berries were calculated from the expression : nutrient removal from soil = yield × (% nutrient concentration /100).

Statistical analysis

The Analysis of Variance (ANOVA) was applied to the data to compare the means. The significant differences between means were determined by the Least Significant Difference method.

Results and discussion

Table 2 presents the range and mean of the percentage N, P and K compositions of the coffee pulp and parchment and beans of the two growth forms from the three locations. The results showed that the N and P contents of the berries at each location were lower in the pulp and parchment than in the bean, while the K content was higher in the pulp and parchment than in the bean.

The higher concentration of K in the pulp and parchment could serve as good source of potash for agriculture, because the coffee husk is normally discarded after hulling. The N, P and K compositions of the pulp and parchment and the

TABLE 2

NPK Composition of Coffee Berries (% Nutrient on Dry Matter Basis)

Nutrient		Nitrogen		Phosphorus		Potassium	
Growth form		Compact	Large	Compact	Large	Compact	Large
				Pulp and parchment			
TAFO	Range	1.38-1.78	1.09-1.73	0.03-0.09	0.05-0.09	1.54-4.33	1.80-3.37
	Mean	1.66	1.40	0.068	0.080	2.33	2.57
	SE (≠)	0.07	0.12	0.012	0.008	0.50	0.316
	CV (%)	9.6	19.3	39.4	21.6	48.0	27.5
FUMSO	Range	2.64-3.69	1.28-2.85	0.05-0.08	0.02-0.09	2.26-2.88	1.78-2.40
	Mean	3.17	2.42	0.068	0.056	2.47	2.15
	SE (≠)	0.16	0.26	0.004	0.012	0.107	0.245
	CV (%)	11.7	26.8	17.6	46.5	9.6	25.5
BECHEM	Range	1.25-1.48	1.17-1.52	0.01-0.10	0.06-0.09	1.25-7.45	3.36-4.57
	Mean	1.38	1.37	0.058	0.074	3.62	4.04
	SE (≠)	0.04	0.07	0.005	0.006	0.208	0.294
	CV (%)	7.5	11.6	16.9	18.1	3.3	16.3
				Bean			
TAFO	Range	2.27-2.98	1.92-3.17	0.08-0.09	0.06-0.10	1.36-2.24	1.20-1.78
	Mean	2.51	2.68	0.086	0.084	1.70	1.64
	SE (≠)	0.13	0.23	0.002	0.006	0.189	0.126
	CV (%)	11.7	19.3	6.4	18.0	24.9	17.2
FUMSO	Range	1.31-2.13	1.29-3.04	0.08-0.10	0.07-0.14	1.68-4.57	1.25-3.37
	Mean	1.57	1.71	0.086	0.092	2.89	2.32
	SE (≠)	0.15	0.33	0.004	0.014	0.544	0.337
	CV (%)	21.2	25.3	10.4	24.7	42.1	32.5
BECHEM	Range	1.85-3.25	2.51-3.15	0.08-0.11	0.08-0.10	1.97-2.88	1.59-3.61
	Mean	2.76	2.83	0.092	0.090	2.40	2.38
	SE (≠)	0.25	0.12	0.006	0.004	0.160	0.36
	CV (%)	20.3	9.1	14.2	11.1	14.9	34.5

beans were not significantly different among the compact and large growth forms at all the locations.

Table 3 presents the calculated amounts of N, P and K removed from the soil in the harvested coffee berries at each location over a 3-year period.

The amounts of N and K removed in the harvested berries were significantly ($P<0.05$) higher in the berries from Tafo and Fumso, the suitable and moderately suitable sites respectively, than in those from Bechem, the marginally suitable site. The amounts of nutrients removed in the coffee berries related positively to the yield at each location for both growth forms.

TABLE 3

NPK Contents of Coffee Berries (kg ha^{-1}) (Percentage Dry Matter)

	Compact growth form				*Large growth form*			
Location	*Average yield (kg ha^{-1})*	*N*	*P*	*K*	*Average yield (kg ha^{-1})*	*N*	*P*	*K*
Tafo	1715.6	36.2a	1.32	34.6a	2146.4	43.8a	1.76	45.2a
Fumso	1606.6	38.1a	1.24	43.1a	2080.4	43.0a	1.54	46.5a
Bechem	373.8	7.8b	0.28	11.3b	478.0	10.0b	0.39	15.3b
Mean	1232.0	273	0.95	29.7	1568.3	32.3	1.23	35.7

* Values with similar letters in a column for each growth form are not significantly different at $P = 0.05$

Yields were higher at Tafo and Fumso where the soils and other environmental conditions such as rainfall were suitable for coffee production (Tables 1a and 1b). The amounts of P removed in the berries were significantly ($P<0.01$) lower than N and K across the locations and for both growth forms. The mean values of nutrients removed from the soil in the harvested berries were 27.3 kg N, 0.95 kg P, and 29.7 kg K ha^{-1}; and 32.7 kg N, 1.23 kg P, and 35.7 kg K ha^{-1} for the compact and large growth forms respectively. These results suggest that the demand for N and K may be higher than P irrespective of the growth form.

Conclusion

The N and K removed from the soil in the harvested coffee berries of both growth forms were significantly higher than P. Addition of just the quantities of the nutrients removed may mean replenishing the soil. Therefore, a fertilizer rate of 30 kg N, 1 kg P, and 33 kg K ha^{-1} could serve as basis for planning the fertilizer requirements of coffee of both growth forms in the main ecological zones where coffee is grown in Ghana.

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