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International Development Research Centre

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Contents

Evaluation of Soil-Testing Methods for Available Potassium in Some Soils of Morogoro

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Of the many cropping systems practiced in Tanzania, intercropping and monocropping are the most common, and they invariably involve the use of fertilizers to supply one or more plant-nutrient elements. Regardless of the cropping system or element involved, it is necessary to rationalize the use of fertilizers to realize justifiable economic returns. This would be possible only when the proper amount of fertilizer is applied to the most needy soil. Soil testing, if conducted using a method suitable to the soil-crop system in question, may be of tremendous use in this respect. A reliable way of choosing a suitable method is by correlating soil-test data, obtained by different methods, with crop response to the applied nutrient element. The method that yields the best correlation is then considered the most suitable for assessing the availability of the nutrient element in question.

Correlation work between soil-test and crop-response data is still in its infancy in East Africa. All too often, fertilizer experiments have been carried out without any prior study of the soil, how representative the experimental site is of the area, or the nutrient needs of the particular crop. Analytical criteria for methods that have been found to be of some value in predicting responses in certain soils have been applied to other soils of different character in the hope that the same criteria could be used to predict responses in these soils. The value of soil analysis in assessing the fertility of tropical soils has been discussed by Nye (1963). An added difficulty with East African attempts to correlate crop responses with soil data has been the variability of East African soils. D'Hoore (1964) lists as many as 29 major soil groups in Tanzania alone, more than in any other country in Africa, and Anderson (1969) has shown that D'Hoore's list is not exhaustive.

Several methods have been developed by researchers in different parts of the world to assess the availability of potassium in soils to crops. The practice in Tanzania, so far, has been for each research station to adapt any method at random, often based upon convenience. This is, however, unsatisfactory in view of the fact that none of the methods developed so far are universally suitable, and there is always a need to select a method suitable to the soil-crop system of interest.

Work on soil-test - crop-response correlation started at the Faculty of Agriculture, Forestry and Veterinary Science of the University of Dar es Salaam during the 1975-1976 cropping season and was carried out over a period of 3 years. Maize (*Zea mays* L.), which is widely used in the Morogoro region as a monocropping or an intercropping crop, was used as the test crop. The results on the suitability of the soil-test methods for nitrogen and phosphorus have been published elsewhere (Singh et al. 1977). The data on the relative suitability of the soil-test methods for potassium are presented here.

Materials and Methods

The sites were chosen so that they differed widely in fertility with respect to K. From each site, a composite surface (0.30 cm) soil sample was collected at planting time, prior to fertilizer application; screened through a 60-mesh sieve; and stored in a refrigerator to keep microbial activity at a minimum. The samples were analyzed for some basic properties using the methods given in Table 1. The samples were also analyzed for potassium

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Table 1. Some initial properties of the soils from the experimental fields.

Parameter	Experimental site										Method[a]
	Mafiga	Hembeti	Mzumbe	Mvumi Primary School	Kilakala Secondary School	Morogoro Secondary School	Wami Vijana Prison	Mlali	Mvomero	Mzinga	
Soil pH (1:1, H_2O)	6.6	7.2	6.7	6.0	6.8	6.1	6.8	6.3	7.0	6.5	Glass electrode pH meter
Organic C(%)	1.88	2.41	1.62	1.68	1.72	1.34	2.07	1.40	1.86	2.17	Walkley-Black
Total N (%)	0.11	0.15	0.12	0.11	0.13	0.14	0.13	0.11	0.14	0.18	Macro-Kjeldahl
Available P (ppm)	47.4	62.8	41.7	47.7	56.1	40.0	92.7	58.3	23.9	72.7	Truog (1930)
CEC (meq/100 g)	24.0	21.0	22.5	35.0	40.0	23.0	30.5	17.5	17.0	36.0	Ammonium saturation
Exchangeable bases (meq/100 g soil)											In NH_4OAc extract by
Ca	6.33	15.68	4.95	9.08	6.33	6.60	14.30	4.40	9.35	9.08	EDTA titration
Mg	2.65	2.65	8.25	7.95	3.83	2.65	4.42	1.77	4.42	4.42	
K	1.20	2.36	1.19	1.28	1.52	1.96	2.28	1.76	1.80	2.32	Flame photometry
Na	0.08	0.13	0.08	0.19	0.20	0.12	0.23	0.08	0.11	0.10	
Base saturation (%)	43	99	66	53	30	49	71	46	92	44	
Particle-size distribution (%)											Bouyoucos hydrometer
Clay	38	14	58	46	30	47	32	41	9	51	
Silt	7	30	12	14	7	9	12	8	9	14	
Sand	55	56	30	40	63	44	56	51	82	35	
Textural class[b]	SC	SC	C	C	SC	C	SC	SC	LS	C	USDA triangle

[a]As described in Black (1965).
[b]SC = sandy clay, C = clay, LS = loamy sand.

by various methods. The following extractants were tested: neutral 1 N NH_4OAc (Metson 1956), cold H_2SO_4 (Hunter and Pratt 1957), hot HNO_3 (Wood and DeTurk 1941), 0.03 N NH_4F + 0.025 N HCl (Bray and Kurtz 1945), 0.002 N H_2SO_4 buffered at pH 3 (Truog 1930), and 0.75 N HCl (Jowrski and Barber 1959).

At each site, a replicated field experiment was conducted with three rates, i.e., 0, 50, and 100 kg/ha, of K, applied (broadcasted and mixed with the soil) as muriate of potash at planting time. A blanket application of nitrogen (100 kg N/ha, as ammonium sulphate broadcasted at the knee-height stage of the crop's development) and phosphorus (40 kg P/ha, as triple superphosphate drilled at planting time) was made. Maize (Ilonga composite) was sown as a test crop at 75 cm between and 30 cm within row spacings. The grain-yield data from the field experiments were used to calculate the relative yield, defined by Cate and Nelson (1965, 1971), as follows:

$$\text{Relative yield} = \frac{\text{yield for treatment including all but the element in question}}{\text{yield for treatment including all the elements}} \times 100$$

$$= \frac{\text{threshold yield}}{\text{plateau yield}} \times 100$$

The threshold yield was the yield from plots receiving no potassium; the plateau yield was the maximum yield regardless of the amount of potassium applied.

The discontinuous statistical model of Cate and Nelson (1971) was adopted for screening the suitability of the methods. The model utilized the soil-test values obtained by a method and relative yields for the various locations to compute a series of coefficient of determination (R^2) values. The maximum R^2 for an index was abbreviated as R_m^2 and the soil test corresponding to this as the "critical soil test" below which maize may respond to potassium fertilization and above which it might not respond to potassium fertilization. The R_m^2 values for all of the soil-test methods were compared. The method leading to the highest R_m^2 was considered most suitable for the soils being tested. The R^2 plot and scatter diagrams showing the relationship between soil-test values and relative yields (Fig. 1) were prepared following the procedures of Cate and Nelson (1965, 1971).

Results and Discussion

Soil Properties

The experimental sites were situated in diverse agroclimatic areas and represented a wide range of soil types. The soils differed considerably in physicochemical properties (Table 1) and in their fertility and productivity, as revealed by variations in the relative yield among the locations (Table 2). Such variations in soil properties and agroclimatic conditions are desirable for a reliable evaluation of an index and for its wide adaptability.

Table 2. Threshold, plateau, and relative yields for the various locations included in the test.

Site	Threshold yield (kg/ha)	Plateau yield (kg/ha)	Relative yield (%)
Mafiga	1705	2433	70
Hembeti	1130	1490	76
Mzumbe	1598	3155	51
Mvumi Primary School	1723	2948	58
Kilakala Secondary School	3142	3969	79
Morogoro Secondary School	2059	2888	71
Wami Vijana Prison	1796	2321	77
Mlali	2393	3595	67
Mvomero	1747	1826	96
Mzinga	3896	3979	98

Grain Yield

Grain-yield data are presented in Table 2. The threshold yield varied from 1130-3896 kg/ha. It would, therefore, appear that there was a marked difference in the natural soil fertility over the areas where the experiments were conducted. Crop response to applied potassium, presented as relative yield, ranged from 51-98%. The results indicated that an increase in yield of almost 50% might be obtained by using potassic fertilizer on the soils of Mzumbe and Mvumi Primary School. At the same time, the soils from Mzinga and Mvomero showed a low response to potassium application. Their productivity could be limited by other factors such as environmental or inherent edaphic conditions in the soil.

Potassium Extracted by the Various Extractants

The soil-test values for potassium, obtained by the various extractants, are presented in Table 3. The amounts of potassium extracted by the different extractants varied within wide limits. The data indicate that 0.75 N HCl, the extractant developed by Jowrski and Barber (1959), extracted the lowest amounts of potassium from all of the soils.

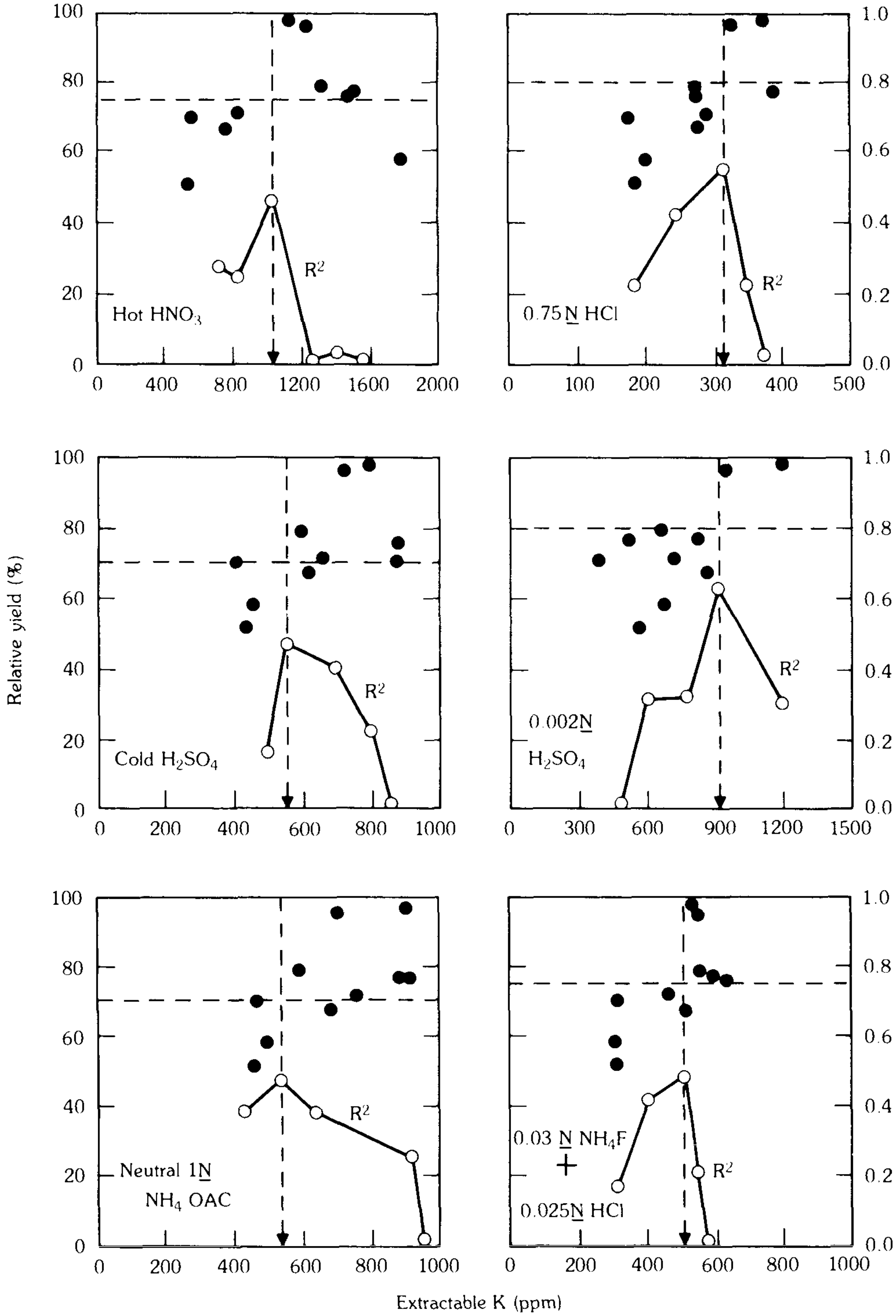

Fig. 1. Coefficient of determination (R^2) plots and scatter diagrams showing the relationship between relative yield and potassium extracted using various extractants.

Table 3. Soil-test values (ppm K) for potassium obtained by the various extractants.

Site	Extractant					
	Neutral 1 N NH_4OAc	Cold H_2SO_4	Hot HNO_3	0.03 N NH_4F + 0.025 N HCl	0.002 N H_2SO_4	0.75 N HCl
Mafiga	469	420	592	320	400	180
Hembeti	921	875	1500	635	524	279
Mzumbe	463	435	560	320	574	191
Mvumi Primary School	500	455	1800	310	674	203
Kilakala Secondary School	594	600	1328	556	674	279
Morogoro Secondary School	763	660	840	468	724	297
Wami Vijana Prison	890	875	1520	600	820	394
Mlali	688	620	784	508	872	279
Mvomero	703	725	1248	556	950	329
Mzinga	906	800	1120	545	1200	349

Pathak et al. (1975) had similar results with some Indian soils. Hot HNO_3 extracted the largest amounts of potassium in almost all cases. This can be explained by the fact that the hot HNO_3 extracts both exchangeable and slowly available forms of potassium (Schmitz and Pratt 1953), whereas the other extractants extract mainly exchangeable potassium.

Relative Suitability of the Extractant for Available Potassium

The relationship between relative yield and soil-test values obtained using each of the extractants is shown in Fig. 1. The methods involving the use of neutral 1 N NH_4OAc, cold H_2SO_4, hot HNO_3, and 0.03 N NH_4F + 0.025 N HCl gave the same coefficient of determination (R_m^2 = 0.47, P <0.01); the respective critical soil-test values were 545, 555, 1040, and 505 ppm. It appears that any of these four methods can be used for assessing potassium availability to plants in the soils of the Morogoro region. Although all four methods appear suitable, the choice of the preferred method will depend upon what other information is needed. The neutral normal ammonium acetate method would be preferred in circumstances where one also needs to determine other exchangeable cations in the same extract. If phosphorus is also to be determined in the same extract, then the 0.03 N NH_4F + 0.025 N HCl (Bray and Kurtz 1945) method would be handy for both elements. The cold sulphuric acid method has the advantage over the neutral normal ammonium acetate and hot nitric acid methods of being simple and less time consuming.

Another extractant that yielded a high coefficient of determination (R_m^2 = 0.56, $P < 0.001$) was 0.75 N HCl (Jowrski and Barber 1959), and this extractant might be used in the routine analysis of farmers' soils with a high degree of predictability. The critical soil-test value was 315 ppm K and maize grown in soils with less than this value would be expected to respond to potassium fertilizer application.

The extracting solution 0.002 N H_2SO_4 buffered at pH 3 (Truog 1930) gave the highest coefficient of determination (R_m^2 = 0.63, $P < 0.001$). This extracting solution accounted for 63% of the variations in the relative yield of maize. The critical soil-test value obtained by this method was 910 ppm K.

Using the criterion that the method leading to the highest coefficient of determination is the best, Truog's method would be rated as the most suitable and could be adopted for the routine analysis of farmers' soils for advisory purposes.

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Discussion

Vander Zaag (question): In your experiment, all of the soils were very high in soil-test potassium (>1 mg/100 g). Why did you not choose/identify one or more soils with lower potassium levels to give a better index of potassium status and requirements?

Uriyo (answer): In the Morogoro region, the soil is like that. In 1974, the government proposed a scheme to provide free fertilizer to farmers but we did not know how much fertilizer should be provided. Hence, this work was initiated to determine the farmers' fertilizer requirements.

Teri (question): Will the conclusions be that Truog's method was the most suitable and applicable to other regions of Tanzania?

Uriyo (answer): This method was specific for the area in which the study was conducted. It will be repeated in other areas because potassium and other nutrient levels are not the same in other areas.

Miany (question): Evaluation of soil-test methods was accomplished with a maize crop (monoculture). How does this relate to intercropping systems where competition or complementary effects between crops are taking place?

Uriyo (answer): The same method can be used if the crop is grown in a systematic way (configuration). When it comes to applying methods to other situations, it needs criterial studies.

Doto (question): The suitability of a soil-test method would best be fitted to soil types rather than to regional (political) areas. Would you comment on this?

Uriyo (answer): If you look at the soil classification of one region, the same order may be found in other regions. Variability of soil types comes from the interaction between the climate and the soil type.