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The Response to Potassium and Uptake by Maize (*Zea mays* L) on Two Malaysian Soils

PELI MAT[1], AMINUDDIN HUSSIN and OTHMAN YAACOB
Soil Science Department, Faculty of Agriculture, Universiti Pertanian Malaysia

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RINGKASAN

Satu kajian di dalam pasu untok mengetahui kesan empat tingkat rawatan K (0, 100, 200 dan 300 kg K_2O/ha) terhadap jagong di atas tanah2 yang kekurangan K dan berlainan tekstur (Munchong dan Serdang) telah dijalankan selama tiga bulan. Beberapa larutan pengeluar K juga telah di kaji.

Di dapati rawatan 100 kg K_2O/ha memberi hasil berat kering jagong yang bermaana di atas tanah Serdang yang berpasir, rawatan yang lebih tinggi tidak memberi perbezaan. Rawatan di tingkat ini juga memberi hasil berat kering jagong yang bermaana di atas tanah Munchong berliat. Jumlah pengambilan K dari tanah Munchong oleh jagong adalah lebih tinggi di bandingkan dengan pengambilan dari tanah Serdang di tingkat rawatan 200 kg K_2O/ha.

Pengeluaran K oleh larutan CH_3COOH memberi pertalian yang bermaana dengan bahagian batang jagong di tanah Serdang (r = 0.921) dan dengan bahagian daun di tanah Munchong (r = 0.819).

SUMMARY

*The response to four levels of K fertilizer (0, 100, 200 and 300 kg K_2O/ha) by maize (*Zea mays *var. Metro) on two known K-deficient soils of different texture (Munchong and Serdang) formerly under rubber, was studied in a pot experiment for three months, in relation to various K extraction methods.*

A significant increase in the dry matter yield of maize was found in the sandier Serdang soil, with 100 kg K_2O/ha; higher levels did not give increased yields. At 100 kg K_2O/ha level, dry matter yield response was also detected for clayey Munchong soil, but the total K uptake was significantly higher at 200 kg K_2O in this soil than in Serdang soil.

Extractable K by CH_3COOH gave the highest significant correlation with the stem portion in Serdang soil (r = 0.921) and with the leaf in Munchong soil (r = 0.819).

INTRODUCTION

Oxisols and Ultisols are known to be deficient in K mainly because of leaching. Crops grown on such soils usually suffer from K deficiency. Potassium concentration in maize differs from one part of the plant to another. A knowledge of the portion of the plant which should be sampled to give the best indication of K availability in soils will aid in the fertilization programme of this crop in the field. Barrow (1966), studying the supply of K to subterranean clover considered K concentration in the plant as a measure of K supply from the soil. Ommen and Iswaren (1967), working with soils of varying texture in India, found that there was a significant correlation between K extracted by 0.5 N HNO_3 and plant uptake on light soils. This was similarly observed by Richard and McLean (1961) who worked on three Ohio soils of different textures. However, Schmitz and Pratt (1953) found that the amount of K extracted by HNO_3 provided a better index than the exchangeable K in predicting response to K fertilization.

1 Present address: Soil Science Department, University of Ghent, Ghent, Belgium.
Key to authors' names: Peli, M, Aminuddin, H, and Yaacob, O.

The objective of this study was to find out which soil extractant should be used and which part of the maize plant should be sampled to give the best indicator of K supplying power of two Malaysian soils (Serdang and Munchong), the two known K deficient soils being of different textures.

MATERIALS AND METHODS

Soils

The two Malaysian soils used in this study were Munchong soil (Typic Haplothox) representing the Oxisol and the Serdang soil (Oxic Paleudult) representing the Ultisol. Only the top 15 cm of these soils were taken because this is usually the root zone of maize plants. Complete chemical and physical analyses of these soils were also carried out using standard methods. (Pratt 1965, Woodruff and McIntosh 1960, Metson 1961).

Pot experiment

For each soil order, 16 clay pots (32 cm diameter and 35 cm height), each containing 18 kg air dry soil were prepared. Four levels of K fertilizer (K_0, K_1, K_2 and K_3) referring to 0, 100, 200 and 300 kg K_2O/ha using Muriate of Potash (60% K_2O) as a source of K were used. A basal dose of Sulfate Ammonia (21% N), Triple Superphosphate (46% P_2O_5) and commercial CaO as source of N, P and lime respectively, was applied to all 32 pots giving to each an equivalent to 175 kg N/ha, 250 kg P_2O_5/ha and 500 kg lime/ha. All 32 pots, four replications for each treatment level, were placed into four blocks using complete randomized block design. Five maize (*Zea mays* var. metro) seeds were sown in each pot and after germination they were thinned to one plant per pot. These pots were left in the open and watered manually as required.

Plant sampling and analysis

All plants were harvested three months after planting and divided into seven components – leaf, stem, root, grain, cob, inflorescence and husk. The plant fractions were oven dried (105°C) for four days, chopped into smaller pieces, subsampled, and ground using the Wiley mill to pass through 0.2 mm screen. The total K content in all plant parts was determined using the dry ashing procedure (Chapman and Pratt 1961) and the K content determined on the EEL-flame photometer.

Soil sampling and analysis

Four core samples were taken from each pot with an auger at harvest, bulked, air dried, ground and sieved. The K content of soil was extracted by appropriate extractants using soil: extractant ratio as given in Table 1. The K content in the extractants was determined on the EEL-flame photometer.

RESULTS AND DISCUSSION

The chemical composition of the two soils is presented in Table 2. Serdang soil (Ultisol) has a lower cation exchange capacity, % carbon, % nitrogen, exchangeable K and clay content compared to Munchong soil (Oxisol). Extractable K by five extractants showed lower values (0.02 to 0.16 me/100g) in the Serdang soil than in Munchong soil (0.14 to 0.31 me/100g). This could be due to the sandy texture of the Serdang soil which made it more susceptible to leaching. On the other hand, higher clay and organic matter contents of the Munchong soil favour retention of K ions making it less susceptable to leaching.

The amount of extractable K in Munchong soil was almost double that of Serdang soil for all extractants used. Of the five extractants used, exchangeable K by I N ammonium acetate released five times more K from Munchong than from Serdang soil. In sandy soils, where the inherent K content is low, boiling HNO_3 was able to extract the most K. These results are in agreement with those of Ommen and Iswaren (1967). According to Hunter and Pratt (1957) acids are able to extract more K than other extractants because:

a) being highly dissociated in H_2O, they furnish H ions effective in displacing K from exchange sites.

b) they are effective agents in breaking down primary and secondary minerals releasing K from crystal lattices.

c) they oxidised organic matter found on the surfaces of soil colloids thereby releasing K in organic fraction.

The effect of different rates of K treatments on the amount of extractable K, dry matter yield and K uptake by the plants are presented in Table 3. In Serdang soil there was a significant increase in dry matter yield when an equivalent of 100 kg K_2O/ha was given. Increasing the levels to 200 and 300 kg K_2O/ha (treatments K_2 and K_3) however did not increase the dry matter yield further. The amount of K taken up by maize plants (total K in the whole plant parts in me/pot) followed the same trend as that of the dry matter yield, where differences due to 100 kg

TABLE 1
Methods of extraction

Extractant	Method and time of extraction	Soil to extractant ratio
Boiling Nitric acid	Boiled mixture for 10 mins.	2.5 g : 25 ml
Cold Sulfuric acid	Stand mixture for 30 mins.	10 g : 25 ml
0.01 M Calcium chloride	Shaking intermittently for 1 hour	5 g : 35 ml
0.5 N Acetic acid	Shaking for 1 hour	5 g : 50 ml
I N Ammonium acetate	Leached through leaching	100 ml of leachate

TABLE 2
Chemical analysis of soils used in the experiment.

Soil Series	Texture sand	Texture silt	Texture clay	pHw 1:2.5	pHkcl	C.E.C me/100 g	Exchangeable cations me/100 g Na	K	Ca	Mg	C %	N %
Serdang	68	4	28	4.6	3.3	6.45	0.01	0.07	0.14	0.32	0.86	0.06
Munchong	23	9	68	4.8	3.4	7.01	0.04	0.47	1.53	0.08	3.51	0.12

	Extractable K (me/100 g) 1	2	3	4	5
Serdang	0.16	0.02	0.03	0.04	0.07
Munchong	0.31	0.14	0.14	0.18	0.47

1 – Boiling N HNO_3
2 – Cold H_2SO_4
3 – 0.01 M $CaCl_2$
4 – 0.5 N acetic acid
5 – I N ammonium acetate

TABLE 3
Means of extractable K for the five extraction methods.

Soil Series	K treatments	K extracted (m.e./pot*) 1	2	3	4	5	Total Dry matter (g/pot)	K uptake (me/pot)
Serdang	K0	26.5	7.7	2.7	2.7	5.5	170.5	13.4
	K1	36.5	11.2	6.4	8.8	11.4	347.5	49.3
	K2	38.1	11.3	10.3	12.9	17.5	393.3	74.6
	K3	48.2	19.6	15.0	21.0	24.6	357.3	78.0
Munchong	K0	24.3	8.2	5.7	7.3	13.6	261.8	25.6
	K1	28.7	12.7	6.4	8.7	19.7	324.5	51.1
	K2	35.6	16.7	12.8	18.9	30.0	257.5	99.2
	K3	34.0	18.9	14.8	20.5	28.0	382.0	92.6

1 – Boiilng N HNO_3
2 – Cold H_2SO_4
3 – 0.01 M $CaCl_2$
4 – 0.5 N acetic acid
5 – 1 N ammonium acetate
* each pot contained 18 kg. of air dried soil
Bracketted means are not significantly different ($P \leqslant 0{\cdot}05$)

K_2O/ha were significant when compared with the control. This showed that due to the sandy nature of the Serdang soil, fixation of applied K could be considered negligible thus applied K fertilizer may be either absorbed by plants or lost by leaching more readily. Higher applications of K fertilizers (200 and 300 kg K_2O/ha) did not significantly increase K uptake by maize plants. These rates might have been above the optimum amount of K required by maize on this soil.

Boiling HNO_3 extractant extracted the most K out of this soil followed by H_2SO_4, NH_4OAC, CH_3COOH and $CaCl_2$ in a descending order. All extractants were able to differentiate between 0 kg K_2O/ha treatment with 300 kg K_2O/ha treatment. None of the extractants was able to differentiate between all the four K treatment levels. This may be due to the difference in forms of K in soil extracted by the extractants. Except for HNO_3, all extractants extracted less K compared to the K taken up by the test plants.

In Munchong soil also, differences in dry matter yield were significant only due to K_1 treatment (100 kg K_2O/ha). The amount of K uptake (me/pot) was only significant at the K_2 treatment (200 kg K_2O/ha). This suggested that the concentration of K present in dry matter of plants can be lowered due to increase in the dry matter weight (Table 3). At high treatment levels, K uptake by plants was higher than extractable K by all extractants showing that the test plants were more efficient in taking up K from this type of soil.

Potassium concentration (me/100g) in the various parts of the maize plant in both soils are presented in Table 4. In both Serdang and Munchong soils, K concentration in the vegetative parts of maize (leaf, stem and root) responded to K treatments whereas K concentrations in the yield components (grain, cob, inflorescence and the husk) did not. At low K treatment, concentration of K in the vegetative parts was low but K concentration in the yield components parts was kept constant, suggesting the mobility of this nutrient in the maize plants.

The correlation coefficients between the various soil extractants and total K uptake by the whole maize plant were positively significant. (Table 5). For Serdang soil, K extracted by CH_3COOH gave the best correlation ($r = 0.722$, $p \leqslant 0.01$), followed by NH_4OAC, boiling HNO_3, $CaCl_2$ and cold H_2SO_4. In Munchong soil higher correlations were obtained, the highest being with CH_3COOH ($r = 0.835$, $p \leqslant 0.001$), followed by $CaCl_2$, NH_4OAC, Cold H_2SO_4 and boiling HNO_3. To some extent the fertility level of the soil for the growing of future crops can be estimated from tissue analysis of leaf or plant parts at harvesting time by correlating the response to levels of K by different plant components with soil extractable K (Table 6).

In Serdang soil, only the stem and root portions gave significant correlations with all extractants. The correlation between stem and extractable K by CH_3COOH was highly significant ($r = 0.921$, $p \leqslant 0.001$). In Munchong soil, all vegetative components gave significant correlations with all extractants. None of the yield components was significant with any of the extractants. The highest significant correlation was obtained with CH_3COOH and the leaf ($r = 0.981$, $p \leqslant 0.001$). The fact that two different

TABLE 4
K concentration in various parts of maize plant (me/100 g)

Soil Series	K treatment	Concentration in plant parts (me/100 g)						
		Leaf	Stem	Root	Grain	Cob	Inflo.	Husk
Serdang	K0	7.24	4.54	8.89	n.a.	24.30	16.95	7.29
	K1	15.67	12.21	16.56	15.75	21.81	8.89	9.53
	K2	20.67	17.71	25.19	14.66	17.27	8.76	13.97
	K3	14.26	25.45	38.11	15.22	22.83	10.42	13.59
LSD0.05		9.97	7.17	8.93	3.68	4.38	4.66	5.24
Munchong	K0	6.84	2.36	12.28	13.04	21.74	12.85	8.22
	K1	16.56	11.96	25.26	12.41	21.23	11.06	10.23
	K2	36.13	44.82	31.52	12.21	23.15	15.66	11.13
	K3	33.76	29.48	30.56	14.58	21.23	9.97	13.78
LSD0.05		11.97	25.3	11.73	1.96	5.04	5.99	5.21

n.a. – data not available.

TABLE 5

Correlation coefficients (r) of total K uptake by the maize plant with K extracted by the five methods.

Soil Series	Extractants				
	1	2	3 Correlation coefficients (r)	4	5
Serdang	0.671**	0.522*	0.600*	0.722**	0.692**
Munchong	0.676**	0.705**	0.768***	0.835***	0.737**

$P \leqslant 0.05$*; $P \leqslant 0.01$**; $P \leqslant 0.001$***

1 – Boiling N HNO_3
2 – Cold H_2SO_4
3 – 0.01 M $CaCl_2$
4 – 0.5 N acetic acid
5 – 1 N ammonium acetate

TABLE 6

Correlation coefficient (r) of K content in various parts of maize plant and K extracted by the five methods.

Methods of extraction	Leaf	Stem	Root	Grain	Cob	Inflorescence
			Serdang Series			
H_2SO_4	0.148 ns	0.525*	0.654**	0.097 ns	0.006 ns	−0.036 ns
$CaCl_2$	0.190 ns	0.810***	0.806***	0.021 ns	−0.105 ns	−0.460 ns
HNO_3	0.267 ns	0.807***	0.611*	0.220 ns	−0.44 ns	−0.332 ns
CH_3COOH	0.124 ns	0.921***	0.815***	0.007 ns	−0.116 ns	−0.424 ns
NH_4OAC	0.170 ns	0.673**	0.761***	−0.041 ns	−0.007 ns	−0.311 ns
			Munchong Series			
H_2SO_4	0.690**	0.819***	0.746***	−0.243 ns	0.097 ns	0.251 ns
$CaCl_2$	0.797***	0.569*	0.673**	0.126 ns	0.012 ns	0.049 ns
HNO_3	0.714**	0.619*	0.654**	−0.033 ns	−0.120 ns	−0.055 ns
CH_3COOH	0.981**	0.656**	0.794***	−0.117 ns	0.016 ns	0.100 ns
NH_4OAC	0.741**	0.610*	0.684**	−0.031 ns	0.097 ns	0.295 ns

$P \leqslant 0.05$*; $P \leqslant 0.01$**; $P \leqslant 0.001$***; ns – not significant.

parts, namely, leaf and stem of the maize gave the highest significant correlation with CH_3COOH as an extractant for K on both soils would indicate that the texture of each soil may affect the K concentration in the maize plants and extractable K by the extractants. This had been shown to be so by Ahmad *et al* (1973) for some West Indies soils.

CONCLUSION

Response of maize plants grown on Serdang soil to K fertilization was found at 100 kg K_2O/ha treatments. These were in the form of the dry matter yield and the total K uptake by the plants. In Munchong soil difference in dry matter yield was significant at 100 kg K_2O/ha treatment whilst difference in K uptake by maize was detected at 200 kg K_2O/ha treatment. In both soils K taken up by plants exceeded the amount extracted by CH_3COOH, NH_4OAC, $CaCl_2$ and H_2SO_4. Amount of K extracted by HNO_3 was similar to that taken up by plants when no fertilizer K was applied. The concentration of K in the leaf, stem and root portions, showed responses to K fertilization. Constant K concentration in grain, cob, inflorescence and husk was found in both soils when compared to the control. Acetic acid gave significant correlation (r = 0.921) with K concentration in the stem in Serdang soil and significant correlation (r = 0.981 with K) concentration in the leaves in Munchong soil. To determine the K supplying power of such soils from plant analysis, the stem parts should be used on Serdang soil and leaves on Munchong soil.

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