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THE SOIL POTASSIUM-SUPPLYING CAPACITIES MEASURED BY RESIN METHODS

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ABSTRACT

The soil sustainability in crop production depends on the size of the indigenous sources of plant nutrients in soils. This research studied the relationships between the soil-potassium supplying capacities and plant-potassium uptake and the nutrient balance of potassium in soils. Soil samples were collected from various sites in Wisconsin, USA, and West Java and Lampung, Indonesia. The soil samples were planted with a sorghum-sudan grass cross called Sudax. A solution containing Ca, Mg, N, and S, but without K or trace elements (1/5 strength of Hoagland solution) was used to provide the initial nutrients during the seeding in silica sand and the additional nutrients during the growth period in soils. Sudax were harvested after a five-week growing period, after which the potassium in plant tissue was determined. The soil potassium-supplying capacities were measured using Resin Methods before and after cropping. The results showed that plant-potassium uptake was well-correlated with soil potassium-supplying capacities measured by the Resin Methods. The nutrient balance of potassium was not observed, with the plant-potassium uptake being greater than the changes in the potassium-supplying capacities of soils.

Keywords : Potassium, resin methods, potassium uptake, nutrient balance, weathering, soil test

With the increasing awareness on the importance of safe and sustainable environment, the low-input agricultural systems should gain a higher priority in agriculture practice. This trend has prompted soil scientists to study the indigenous sources of plant nutrients in soils. The nutrient-supplying capacities of soils, therefore, become an important soil property to investigate. Accurate and precise analytical methods to determine this property need to be devised.

Knowledge on the indigenous sources of plant nutrients and some important factors that influence their processes in providing nutrients for plants has been well-documented. Plant nutrients are available to plants from the octahedral as well as from the interlayer positions in the soil minerals. The nonexchangeable elements are readily available to platns during the growing seasons by soil weathering (Pratt, 1952; Thomas and Giddens, 1958; Christensen and Doll, 1973; Feigenbaum and Shainberg, 1975Feigenbaum et al., 1981). The soil weathering is influenced by soil particle size, exchangaeable cations, soluble organic acids, and soil pH (Mortland and Lawton, 1961; Anderson and Wiklander, 1975; Munn *et al.*, 1976; Oster and Shainberg, 1979; Tan 1980; Frenkel *et al.*, 1983; Manley and Evans, 1986; Song and Huang, 1988; Simard *et al.*, 1992). For example, Johnston and Olsen (1972) found that plant roots are able to extract P and other elements from apatite by dissolution process. This process in significantly influenced by: (1) CO_2 excreted by roots and microorganisms, (2) chelating agents excreted by roots, (3) Ca adsorption and absorption by roots, and (4) acidity induced directly by acids exreted by roots. However, efforts to measure the size of the nutrients released by soil weathering quantitatively and the study of the soil nutrient-balance have been minimal, particularly in the area of the soil potassium.

A significant quantitative study on the soil K-supplying capacities was done by Pratt (1951) using a resin system. The potassium released by weathering measured by the resin method was found to be highly correlated with K uptake by alfalfa (*Medicago sativa*). The amount of potassium released by weathering was calculated indirectly as follows:

$$\text{Released K} = \text{Resin K} - \text{Exchangeable K} \qquad \text{Eq.(1)}$$

where Resin K was obtained by incubating a mixture of 5 g soil sample and 5 g of H-saturated resin for two months and Exchangeable K was measured by leaching the soil sample with 2 M NH_4OAc-0.2 M $(Mg(OAc)_2$ solution. The amount of K relased by weathering was also calculated as follows:

$$\text{Released K} = \text{Uptake K} - |\Delta \text{ Exchangeable K}| \qquad \text{Eq.(2)}$$

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Where Δ Exchangeable K was the difference between the exchangeable K before and after cropping. However, this method did not give a direct measurement for K released by soil weathering (K-supplying capacity) and the equilibration time was too long for routine analysis.

Direct measurement of K-supplying capacities can be done using Resin Methods with a fairly short equilibration time (Salam, 1989). The objective of this experiment was to study the relationships between the amounts of K released by soil weathering measured by Resin Methods and those taken by plants and to evaluate the nutrient balance of K in soils before and after cropping with Sudax.

MATERIALS AND METHODS

Soil and Resins

Soil samples encompasing seven soil orders were collected from Wisconsin, USA, and West Java and Lampung, Indonesia. These soils represented different stages of weathering and chemical composition. The soil samples were air-dried and sieved to 100 mesh. Weighings were on an oven-dry basis. The concentrations of selected elements in these soils are given in Table 1.

A stong-acid resin (Dowex 50W-X8), a weak-acid resin (Amberlite DP-1), and a chelating resin (IR 718) were used. All resins were stored in moist condition. Weighings were on an oven dry basis.

Resin Methods

All resins were adjusted to NH_4-form prior to use. After eliminating the fine particles by elutriation with distilled water in a column, all resins were equilibrated sequentially with alcholic M HCl. M NaOH, M HCl, and finally with 0.001 M NH_4NO_3. Alcoholic HCl was to solubilize the organic contaminants produced during manufacturing. The HCl-NaOH-HCl equilibrations were to develop consistent exchange properties (Helfferich, 1962). The last NH_4NO_3 equilibration was to saturate the functional groups with NH_4^+ at an ionic strength equal to 0.001 M. A pH-buffered mixture was then prepared from one part of weak-acid resin and two parts of chelating resin with enough dilute NH_4OH

Table 1. Concentration of selected elements in soils[1]

Soil origin	Soil order	pH	Ca	Mg	K	Al	Fe	Mn	Zn	Cu	Si	P
			Exchangeable + dissolved or dossolved elements									
			mg/kg^{-1}									
Indonesian soils[2]												
Cihea	Vertisol	7.58	6270	801	117	tr[3]	5	42	tr	tr	3785	55
Darmaga	Oxisol	4.98	218	65	44	140	2	498	2	tr	98	tr
Gedongmeneng	Oxisol	6.00	1200	227	227	tr	4	2	3	1	175	tr
Jasinga	Ultisol	4.74	445	508	160	2200	24	76	21	6	92	tr
Rajamandala	Entisol	6.28	3830	834	188	tr	2	20	1	tr	256	64
Sindangbarang	Entisol	6.24	917	268	112	tr	2	10	1	tr	121	7
Sukamantri	Inceptisol	4.75	240	33	67	63	2	12	2	tr	193	tr
Wisconsin soils[2]												
Keewaunee	Alfisol	7.39	2250	841	476	tr	tr	5	2	2	158	174
Plainfield	Entisol	6.43	784	223	385	23	2	13	1	tr	40	48
Plano (top soil)[4]	Mollisol	5.94	1950	433	62	tr	3	13	1	tr	97	6
Plano (sub soil)	Mollisol	5.34	1203	311	52	49	3	7	2	tr	66	1
Withee (top soil)	Alfisol	5.13	697	138	35	116	3	35	3	tr	36	2
Withee (sub soil)	Alfisol	5.02	761	181	38	103	5	11	4	tr	45	7

[1] average of 3 replicates; [2] Gedongmeneng from Lampung and others from West Java, Indonesia; [3] trace; [4] top soil 0-20 cm and subsoil 20-40 cm depth.

solution to set a pH of 4.5. After an equilibration, the excess solution was removed by suction and the resins were stored in moist condition.

The Resin Method was originally designed to measure all macro and microcations (Salam, 1989). In this experiment, however, this method was used only to measure K. In so doing, 2 g soil was weighed into a 50-ml Oak-Ridge-type centrifuge tube and was extracted twice with 20 ml of M NH_4NO_3 and 3 times with 20 ml of 0.001 M NH_4NO_3 to remove all the exchangeable and dissolved cations. One gram of strong-acid resin and three grams of the pH 4.5-buffered resins-mixture were added. The mixture was mixed and equilibrated with 20 ml of 0.001 M NH_4NO_3. The final 100 ml extract was used for the K determination. The K concentrations were measured with flame photometer after filtration through 0.45 μm millipore filter.

Greenhouse Experiment

To determine the plant K uptake, twenty seeds were planted in 600 g of silica sand in a bottomless cardboard pot nested within a second carboad pot (Fig. 1-a). A solution containing Ca, Mg, N, P, and S, but without K or trace elements (1/5 strength of Hoagland solution) was added to provide intial nutrients. The seedlings were thinned to ten after 5 days. After a root mat had formed at the bottom of the pot, the seedlings along with the sand and the bottomless pot was placed atop soil or silica sand in a third cardboard pot containing 200 g of soil sample or silica sand (control). The Hoagland solution was added continually during the growth period by capillary action along a wick inserted through the bottom of the soil-containing pot (Fig. 1-b). Each treatment was replicated 3 times.

The plant shoots were harvested after 5 weeks and the yield and K uptake were determined. Plant shoot samples were immediately oven-dried at 60°C for about 48 hours. The oven-dried materials were weighed to obtain the oven-dry weight, and ground in a Willey mill to pass a 20-mesh sieve. The ground materials were thoroughly mixed and stored in an air-tight jar. To measure the K content, about 0.15 g of oven-dry ground material was weighed and extracted with 20 mL of M NH_4OAc at pH 7. The extract was passed through a Whatman No No. 2 filter paper and anlyzed for K content with flame photometer (Wilde *et al.*, 1979). The soils were analyzed for the exchangeable and dissolved K and the resin-released K by Resin Methods before and after cropping.

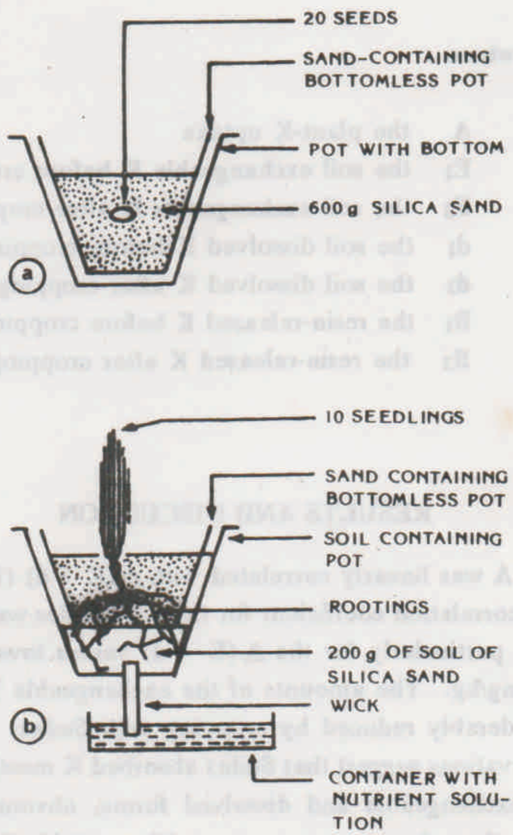

Figure 1. Greenhouse experiment setup: pot arrangements for: a. seeding and b. plant growth.

Nutrient Balance

The Resin Methods extracted all forms of K available to plants during the growing period. The total content of these form is called the soil potassium-supplying capacity. The extraction before the equilibration (twice with 20 mL of M NH_4NO_3 and 3 times with 0.001 M NH_4NO_3) extracted both the dissolved K (d) and the exchangeable K (E). The extraction after the equilibration with the resin system (once with 0.001 M NH_4NO_3 and 4 times with 0.005 M EDTA in M NH_4NO_3) extracted all K assumed to be released by the weathering processes (B).

The nutrient balance was evaluated with the following equation:

$$A - |\Delta(E + d)| - |\Delta B| = 0 \quad \text{Eq. (3)}$$

$$\Delta(E + d) = (E + d)_2 - (E + d)_1 \quad \text{Eq. (4)}$$

$$\Delta B = B_2 - B_1 \quad \text{Eq. (5)}$$

where :

- A the plant-K uptake
- E_1 the soil exchangeable K before cropping
- E_2 the soil exchangeable K after cropping
- d_1 the soil dissolved K before cropping
- d_2 the soil dissolved K after cropping
- B_1 the resin-released K before cropping, and
- B_2 the resin-released K after cropping

RESULTS AND DISCUSSION

A was linearly correlated with $\Delta(E + d)$ (Fig. 2). The correlation coefficient for these variables was fairly high, particularly for the $\Delta(E + d)$ values lower than 200 mg/kg. The amounts of the exchangeable K were considerably reduced by cropping with Sudax. These observations suggest that Sudax absorbed K mostly from the exchangeable and dissolved forms, obviously because these forms were more readily available for plant growth. The slope of the correlation line indicates that the amount of K absorbed from these forms were

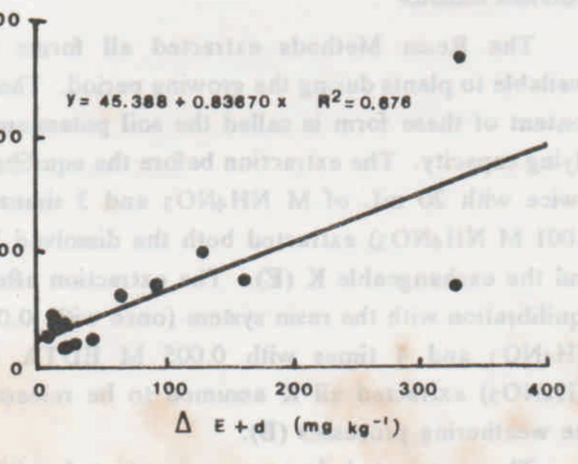

Figure 2. Relationships between A and $\Delta(E + d)$

roughly about 84% in average. This finding is in accord with the observations reported by Conyers and McLean (1969) in soils cropped with German millet (*Setaria italica stramineofructa*) and alfalfa (*Medicago sativa*).

However, the fact that the values of A were greater than the values of $\Delta(E + d)$ also suggests that some of the K taken by Sudax might have come from the nonexchangeable K. This form of K may have become available by weathering processes during the Sudax growth. Dissolution of K-containing minerals was possible because of the chemical or biological action of Sudax roots.

A was linearly correlated with B_1 or B_2 (Figs. 3 and 4), with A being higher at higher values of B_1 or B_2. These observations give additional evidence that some of the K uptake was originated from the nonexchangeable forms released into the soil solution by weathering processes and finally absorbed by the Sudax roots. These observations also suggest that the Resin

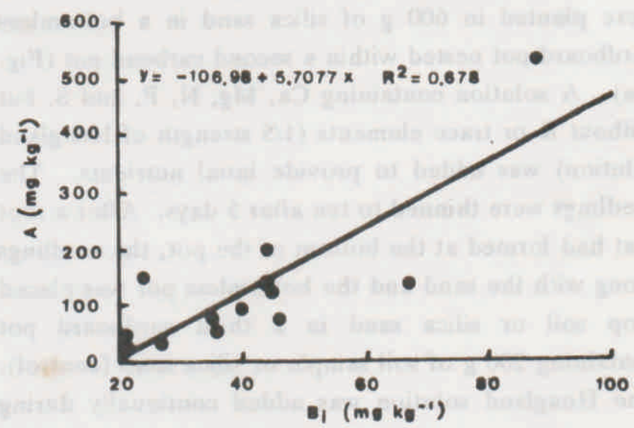

Figure 3. Relationships between A nd B_1.

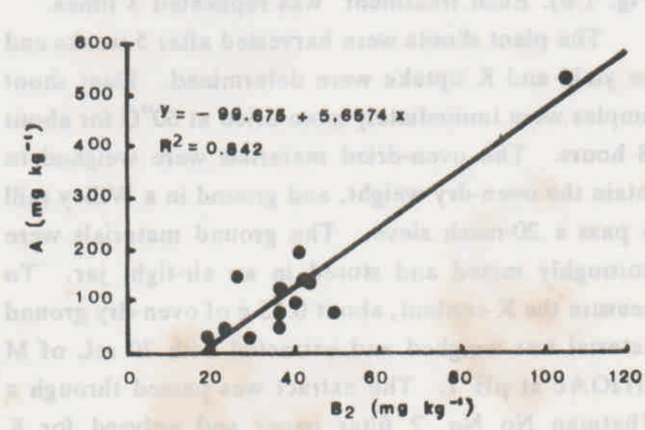

Figure 4. Relationships between A and B_2.

Methods provide a good measure for the released K by weathering.

The resin released K before and after cropping with Sudax did not differ significantly. However, the values of ß were linearly correlated with ΔB (Fig.5), in which:

$$ß = A - |\Delta (E + d)| \quad \text{Eq. (6)}$$

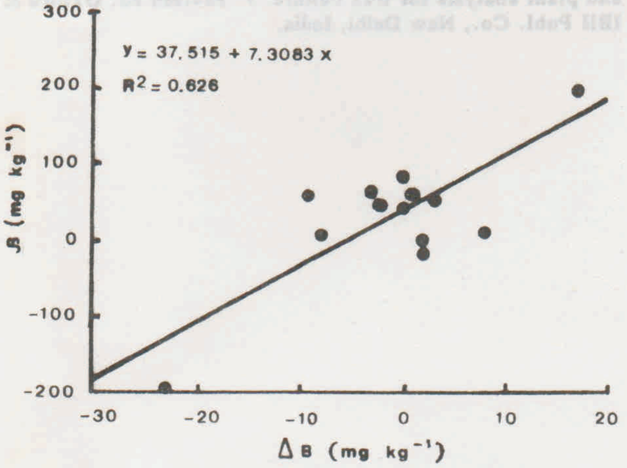

Figure 5. Relationships between ß and Δ B.

This relationship also suggests that the K not originated from the exchangeable or dissolved forms was contributed by the nonexchangeable forms. The Resin Method at pH 4.5 was not sensitive enough to measure the difference in the K released by weathering. By lowering the pH value of this method, it must be possible to observe the changes in the resin-released K by cropping (Salam, 1989).

The nutrient balance of K calculated by Eq. (3) was not observed in this experiment. The uptake of K was greater than the changes in the exchangeable and dissolved K plus those contributed by soil weathering, except for plainfield soil. The fixation of K in plainfield soil, which may have been induced by cropping with Sudax, may have caused some of the exchangeable and dissolved K become no nexchangeable. Another probability is that, in this particular soil, the uptake K may have accumulated more in the root rather than in the shoot. This suggests that including the plant root in plant tissue analysis is necessary. However, based on the previous experiments (Salam, 1989), the nutrient balance of K is possible to observe by adjusting the pH of the resin system.

CONCLUSIONS

Sudax absorbed K mostly from the exchangeable and the dissolved forms. The results of this experiment suggested that the plant K uptake was partially contributed by the release of nonexchangeable K by weathering processes. The Resin Methods at pH 4.5 showed a good relationship with the K taken by Sudax suggesting that the Resin Methods can give a good estimate for the K released by weathering. However, to evaluate the nutrient balance, a lower pH value and may be some modifications of the methods are needed.

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