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The Soil Available-Potassium Enrichment by Several Potential Tropical Weeds

Abdul Kadir Salam[1,a)], N Sriyani[2], SK Dewi[1] and M Utomo[1]

[1]*Department of Soil Science, Faculty of Agriculture, University of Lampung, Bandar Lampung, Indonesia*
[2]*Department of Agronomy and Horticulture, Faculty of Agriculture, University of Lampung, Bandar Lampung, Indonesia*

[a)]*Corresponding author: abdul.kadir@fp.unila.ac.id*

Abstract. Plant nutrient release from soil minerals is reported to be speeded at lower soil pH, which is also governed by the acidifying effect of vegetation roots. This research was to investigate the effects of several tropical weeds on the available K in two tropical soils with distinct properties. Five potential weeds including *Asystacia gangetica*, *Arachis pintoi*, *Widelia* sp., *Paspalum conjugatum* and *Pennisetum purpureum* were grown in the soil samples contained in polybags. The soil available K was depleted by weeds except in soils planted with *A. pintoi* as indicated by the positive values of the change in the available K after two monthss growing period, suggesting that *A. Pintoi* root was more effective than the other four weeds in enhancing the soil available K. The effectiveness of weeds in enhancing the soil available K were*: A. Pintoi > A. gangetica > Widelia sp. > P. conjugatum > P. purpureum.*

INTRODUCTION

Potassium is an important nutrient for plant growth and development [1], but problem related to soil potassium is still significant in soil fertility management and its availability is still greatly dependent on the introduction of inorganic fertilizer supplies [2]. To partially cope with this problem the use of indigenous K contained in soil minerals is promising, particularly in soils with minerals high in K [3-6]. In several soils, the amount of soil mineral K is fairly significant. One of the problems is to convert the soil mineral K into forms of K available to plant absorption [5, 7-8].

The use of indigenous soil minerals needs a speeded weathering process to release non-exchangeable K, mainly by managing one or more soil environmental factors. One of the most important problem in converting the soil mineral K into plant available K is the suitable pH for accelerating the weathering of the K-containing soil minerals. The release of K by mineral weathering in general increases with the increase in H^+ concentration [2,4, 8-9]. The presence of more H^+ ion with the decrease in soil pH may enhance the dissolution of the soil K-containing minerals and increase the soil available K. Part of the release K^+ may enhance the available K in the soil exchangeable K [5] and part of it may stay in the soil solution to be absorbed by plants and/or leached by the soil percolating water [2]. In general, the decrease in soil pH may increase the soil available K in the soil system [2,8].

Therefore, the decrease in soil pH is of utmost importance in availing the soil available K and is generally generated in the vicinity of roots of particular plants [8,9]. It was suggested that roots of several weeds may greatly lower the soil pH by excreting H^+ that may lower the soil pH [9,10]. In general, it was reported that plant roots were able to extract P and other elements by dissolution processes which were greatly affected by: (1) CO_2 release by roots and microorganisms and (2) chelating agents and other exudates excreted by roots [6,9, 11-16]. Root organic acids may release more K from soil minerals [7, 8,17]. The presence of the releasing K microorganisms living in plant roots may also increase the detachment of soil mineral K [11,18], probably through their acidifying properties. In addition, weed-plant roots and root-associated microbial communities may also produce enzymes that may accelerate the changes in the unavailable structurally bonded K in the organic residues into readily available inorganic K [19-22]. Some researchers report that the activities of enzymes are significantly higher in the rhizosphere than those in non-rhizosphere soils [19]. Different plants were shown to produce different activities of soil enzymes [23]. In summary, the presence of plant roots may also increase the decomposition of soil organic matters [24]. Several reports show that the belowground C inputs is reported to be higher than the aboveground C inputs [25].

There are numerous weeds potential to employ in this mission [10]. Several grass and broad-leaf weeds were reported to improve the total soil organic matter and the related soil cation-exchange capacity (CEC). It was reported that *P. conjugatum, Crotalaria lappacea*, *Widelia sp.,* and *A. gangetica* were among those significantly increased the

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soil CEC and organic matter content The use of these weeds significantly increased the soil organic matter content to about 200% from its initial value of 5.5 mg kg^{-1} and the soil CEC increased to about 125% from its initial value of 4.45 $cmol_c$ kg^{-1}. Various weeds induced different values of soil pH; those in the root zones of pigweed (*Amaranthus spinosus L.*) and amaranth (*Amaranthus tricolor* L.) were lower than that in the root zone of green kyllingia (*Cyperus kyllingia* L.) and were much lower than that in the root zone of *alang-alang* (*Imperata cylindrica*) [10,19].

This research was to study the changes in the soil available K by several tropical weeds including *Asystacia gangetica*, *Arachis pintoi*, *Widelia* sp., *Paspalum conjugatum*, and *Pennisetum purpureum*. These weeds were suggested to significantly lower the soil pH and increase the soil available K and therefore may increase the availability of K.

MATERIALS AND METHODS

Potential Weeds

Several potential weeds were evaluated in this research. These weeds included *Asystacia gangetica*, *Arachis pintoi*, *Widelia* sp., *Paspalum conjugatum*, and *Pennisetum purpureum*. The seedlings of these weeds were collected from fields and were initially planted and grown for several days in polybags to obtain the best and relatively similar seedlings. The visual properties of the weeds are depicted in **Figure 1**.

Soil Samples

To study the influence of several potential tropical weeds on changes in the soil available K, two tropical soils from Lampung was sampled from two different locations, i.e. Bandar Agung (-5,4117°, 105,383°) Jabung East Lampung, and Serdang (-5,298°, 105,687°) Tanjung Bintang, South Lampung, Indonesia. From each location, a composite soil sample was taken from the depths of 0 – 30 cm (topsoils) and 30 – 60 cm (subsoils). Soil samples were air-dried, ground, sieved to pass a 2-mm sieve, and thoroughly mixed before being used in the green-house experiment. **Table 1** shows that the soil of Jabung was more fertile than that of Tanjung Bintang as shown by the higher soil pH, organic matter content, and exchangeable K.

TABLE 1. Selected properties of soil samples used in this experiment.

Soil Propertiies	Methods	Soil of Jabung		Soil of Tanjung Bintang	
		Topsoil	Subsoil	Topsoil	Subsoil
pH	Electrometry (Water 1:2)	5.81	4.87	5.32	5.67
Organic C ($g\ kg^{-1}$)	Walkley and Black	6.00	3.10	1.00	1.50
Available K ($cmol_c\ kg^{-1}$)	NH_4OAc *N* pH 7.0	0.36	0.29	0.09	0.07

Experimental Design and Procedure

A split-split plot design was employed with three factors that include weeds as the main plot, soil samples as sub-plot, and soil layers as sub-sub plots. The experiment was conducted with three replications. A polybag containing 5 kg of oven-dry equivalent air-dried soil sample was used as an experimental unit.

Ten seedlings of each weed were planted in polybags each containing 5 kg oven-dry equivalent (24 hours 105 °C) air-dried soil sample which have been equilibrated for one week at the soil field moisture capacity or about 40%. The growing weeds were then let to grow for 2 months. No other weeds were allowed to grow in the experimental unit during the growing period.

AG = *Asystacia gangetica*
AP = *Arachis pintoi*
W = *Widelia sp.*
PC = *Paspalum conjugatum*
PP = *Pennisetum purpureum*

FIGURE 1. The five tropical weeds employed in this research (After [10]).

Weeds and soil samples were harvested at the end of the weed growing period. The weeds were cut at the soil surface to obtain shoot fresh-weight and dry-weight. The root parts of weeds were also carefully harvested to obtain root fresh-weight and dry-weight with minimum loss of root parts during the soil mass removal from the root mass using tap water. Dry weight was obtained after putting the fresh weed materials in an oven of 60°C for 3 x 24 hours. Soil samples were also taken from each experimental unit to determine the soil pH, soil total C, and exchangeable K. Soil pH was determined using pH-electrode, total C using the Method of Walkley and Black, and the soil exchangeable K was extracted using 1 *N* NH_4OAc pH 7.0 and determined using a flame photometer. The soil exchangeable K was assumed to be the measure of the soil available K.

RESULTS AND DISCUSSION

The Effect of Weeds on Soil pH, Available K, and Organic Matter

The presence of weeds significantly influenced the soil available K and pH but gave no influences of the soil organic C (**Table 2**). The presence of *A. pintoi* resulted in the highest final soil available K (94.4% of the initial available K) while *P. purpureum* caused the lowest with the difference 0.22 cmol$_c$ kg^{-1} (33.3%) and no differences between *A. gangetica*, *Widelia sp.*, and *P. conjugatum* in soil of Jabung which were 0.11 cmol$_c$ kg^{-1} (64.7%). No different effect on soil available K among the five weeds in soil of Tanjung Bintang (**Table 3**).

A similar trend also occurred on soil pH. *A pintoi* caused the lowest pH in soil of Jabung compared to other weeds (**Table 2**, **Table 4**). The soil pH of Jabung planted with *A. pintoi* was 5.55, 0.13 unit lower than the average soil pH of Jabung planted with the other four weeds, about 5.68. No effect of any weed on soil pH of Tanjung Bintang. However, there were significant differences between the soil pH of Jabung and those of Tanjung Bintang planted with *A. pintoi* and *Widelia sp.*(**Table 1**, **Table 4**).

TABLE 2. Effect of weeds and on soil pH, organic C and available K[a].

Treatment Factors	Soil Properties[b]		
	pH	Organic C	Available K
Main Plot:			
Weed Plant Roots (A)	**	ns	**
Sub-Plot			
Soil Type (B)	**	*	**
AB	**	ns	**
Sub Sub-Plot:			
Soil Layers (C)	ns	**	**
AC	**	ns	**
BC	**	ns	**
ABC	ns	ns	ns

[a]After [10], [b]ns = not significant, *significantly different at 5% HSD test, ** very significantly different at 1% HSD test

TABLE 3. The effect of several weeds on available K in two different tropical soils.

Weeds	Soil[a]	
	Jabung	Tanjung Bintang
	………… cmol$_c$ kg^{-1}	……………
A. gangetica	0.23 b	0.07 a
	B	A
A. pintoi	0.34 c	0.09 a
	B	A
Widelia sp	0.22 b	0.05 a
	B	A
P. conjugatum	0.25 b	0.04 a
	B	A
P. purpureum	0.12 a	0.03 a
	B	A

[a]Different uppercase in one line or lowercases in one column indicate a significant difference by HSD test at 5% level, HSD 5% = 0.07

The Changes in the Soil Available K

The relative changes in the soil available K are presented in **Table 5**. The relative change in available K (Δ Avail K) was calculated by **Equation 1**.

$$\Delta \text{ Avail. K} = \frac{\text{Final Available K (After Planting) – Initia Available K (Before Planting)}}{\textit{Initial Available K}} \text{ x } 100\% \quad \ldots\ldots. \quad \textbf{Eq 1}$$

The Δ Avail K ranged from 28.6-145.0%. The highest were in soils planted with *A. pintoi*, ranging from 85.7-145.0%, and the lowest were in soil planted with *P. purpureum*, ranging from 28.6-44.4%. Δ Avail. K of more than 100% indicates that the final soil available K were higher than the initial soil available K, which means that some amount of K was released from mineral and organic sources exceeding those absorbed by the related weed. The effectiveness of weeds in releasing the soil unexchangeable K to exchangeable (available K) was *A. Pintoi* > *A. gangetica* > *Widelia sp*. > *P. conjugatum* > *P. purpureum.*

TABLE 4. The effect of weeds on pH of two different tropical soils.

Weeds	Soil[a]	
	Jabung	Tanjung Bintang
A. gangetica	5.76 a	5.82 a
	A	A
A. pintoi	5.55 b	5.77 a
	A	B
Widelia sp	5.71 a	5.69 a
	B	A
P. conjugatum	5.65 a	5.90 a
	A	A
P. purpureum	5.61 a	5.87 a
	A	A

[a]Different uppercase in one line or lowercases in one column indicate a significant difference by HSD test at 5% level, HSD 5% = 0.21

TABLE 5. The relative changes in soil available K (Δ Avail. K) as affected by weeds[a].

Soils	Layers	Weeds[b]				
		Ag	Ap	W	Pc	Pp
				% of initial contents[c]		
Jabung	Topsoil	72.2	**114.0**	75.0	83.3	44.4
	Subsoil	65.5	93.1	58.6	69.0	38.0
Tanjung Bintang	Topsoil	88.9	**145.0**	66.7	55.6	33.3
	Subsoil	85.7	85.7	42.9	28.6	28.6
Average		78.1	110.0	60.8	59.1	36.1

[a]After [10]

[b]Ag *A. gangetica*, Ap *A. pintoi*, W *Widelia* sp., Pc *P. conjugatum*, and Pp *P. purpureum*

[c]Initial topsoil and subsoil available K were 0.36 and 0.29 $\text{cmol}_c \text{ kg}^{-1}$, respectively, for soil of Jabung and 0.09 and 0.07 $\text{cmol}_c \text{ kg}^{-1}$, respectively, for soil of Tanjung Bintang

Root and Shoot of Weeds

The root-to-shoot ratio (RSR) of the five weeds planted in two different soils is given in **Table 6**. The RSR of *A. pintoi* were significantly higher than those of the other four weeds. The RSR of *A. pintoi* ranges from 0.521-to1.220. The RSR for the other weeds ranges from 0.125-0.690. The RSR in subsoils were in general with a few exceptions higher than those in topsoils.

The relative changes in the soil available K in soil of Jabung were in general in good correlation with shoot, root and shoot+root dry weight (R^2 = 0.52*-0.81*). The exception was the correlation with root weight in subsoil of Tanjung Bintang (**Table 7**).

TABLE 6. The root-to-shoot ratio (RSR) of weeds grown in two tropical top and subsoils[a].

Soils	Layers	Weeds[b]				
		Ag	Ap	W	Pc	Pp
Jabung	Topsoil	0.203	0.521	0.225	0.395	0.342
	Subsoil	0.418	1.220	0.285	0.372	0.410

Soils	Layers	Weeds[b]				
		Ag	Ap	W	Pc	Pp
Tanjung Bintang	Topsoil	0.274	0.529	0.125	0.202	0.059
	Subsoil	0.690	0.725	0.250	0.340	0.016

[a]After [10], [b]Ag *A. gangetica*, Ap *A. pintoi*, W *Widelia* sp., Pc *P. conjugatum*, and Pp *P. purpureum*

TABLE 7. The correlation coefficients (R^2) between the relative changes in the soil available K and weed biomasses.

Soil	Soil Layer	Root	Shoot	Root + Shoot
Jabung	Topsoil	0.81*	0.73*	0.76*
	Subsoil	0.52*	0.65*	0.62*
Tanjung Bintang	Topsoil	0.54*	0.53*	0.54*
	Subsoil	0.02	0.52*	0.52*

Discussion

Theoretically, the soil available K is measured by dilute salts like 1 *N* NH$_4$OAc buffered at pH 7.0. This method measured all the soil solution K and exchangeable K [2]. The presence of plants roots is suggested to increase the release of unexchangeable to dissolved and exchangeable K as shown in **Figure 2**. The excretion of H$^+$ ion and organic acids by plant roots and also the respired CO$_2$ may lower soil pH [2,10] which may drive the weathering of K-containing soil minerals. The release of K$^+$ ion may increase with the increase in the amount of H$^+$ ion in soil solution, which may act as an attacking agent for the K-containing soil minerals [2]. The released K$^+$ may enter the soil solution increasing the soil soluble K in soil solution and the most part may enter the soil exchange sites to increase the soil exchangeable K. These processes may thus increase the soil available K that include the soil exchangeable (in soil exchange sites) and soluble K in soil solution.

The excreted soil enzymes by plant roots may certainly enhanced the decomposition of the soil organic matters releasing plant nutrients including K. Similar with that released by the soil minerals, the released K from the soil organic matter may increase the soil available K that include the soil exchangeable K and the soil soluble K. Soil enzymes are produced by plant roots. Some microorganisms living in rhizosphere also produce some soil enzymes [10, 9-20). The activities of some soil enzymes in soils are higher in soils inhabited by roots and microorganisms [19-20].

Data collected in this research showed that the soil available K decreased in the presence of weeds (**Table 2** and **Table 3**). The release of K from mineral and organic K did not suffice those absorbed by weeds except in soils planted with *A. pinto*i. As shown in **Table 5**, the lowest relative available K in soils were after planting with *P. purpureum* ranging from 28.6-44.4 while the highest were in soils planted with *A. pintoi*, ranging from 85.7-145.0. *A. pintoi* was shown to effectively produced significant available K exceeding those absorbed. Therefore, the final soil available K was higher than the initial available K with the relative available K > 100%, i.e. 114 and 145% in topsoil of Jabung and Tanjung Bintang, respectively (**Table 5**).

One of the reasons for the more significant effect of *A. pintoi* on the soil exchangeable K compared to other weeds was the extent of its effect on soil pH (**Table 2** and **Table 4**), particularly in soil of Jabung. The soil pH of Jabung planted with *A. pintoi* was 5.55, 0.13 unit lower than the average soil pH of Jabung planted with the other four weeds, about 5.68 (**Table 2**). The lower soil pH means the higher H$^+$ concentration in the soil solution. Since H$^+$ ion is an attacking agent in soil mineral destruction, it may have released more K$^+$ into the soil solution and soil exchangeable sites. As a result, it may elevate the soil available K.

The data clearly shows that weeds absorbed K from soils and depleted the soil exchangeable K during the growing time. The effectiveness of various weeds in absorbing K and causing the exchangeable K depletion are various. *Penisetum purpureum* is the most effective in depleting the soil exchangeable K. The order of their effectiveness in depleting the soil exchangeable K were *P. purpureum* > *P. conjugatum* > *Widelia sp.* > *A. gangetica* > *A. Pintoi*. However, the fact that the soil exchangeable K in soils under *A. pintoi* increased to about 114.0% in soil of Jabung and to about 145.0% in soil of Tanjung Bintag, particularly in topsoils, suggest that the weed also stimulated the release of K from soil mineral structures through weathering processes. The release was at least 14% of the initial exchangeable K in soil of Jabung and 45% of the initial exchangeable K in soil of Tanjung Bintang, assuming that the *A. pintoi* did not absorb K from the soil available K. The soil available K of these soils might have increased more than 14% and 45%, respectively, if weeds absorbed soil K. This suggests that the weeds in fact stimulated the release of soil mineral structural K. The effectiveness of weeds in stimulating the release of soil K or in increasing the soil available K follows the order of: *A. Pintoi* > *A. gangetica* > *Widelia sp.* > *P. conjugatum* > *P. purpureum*.

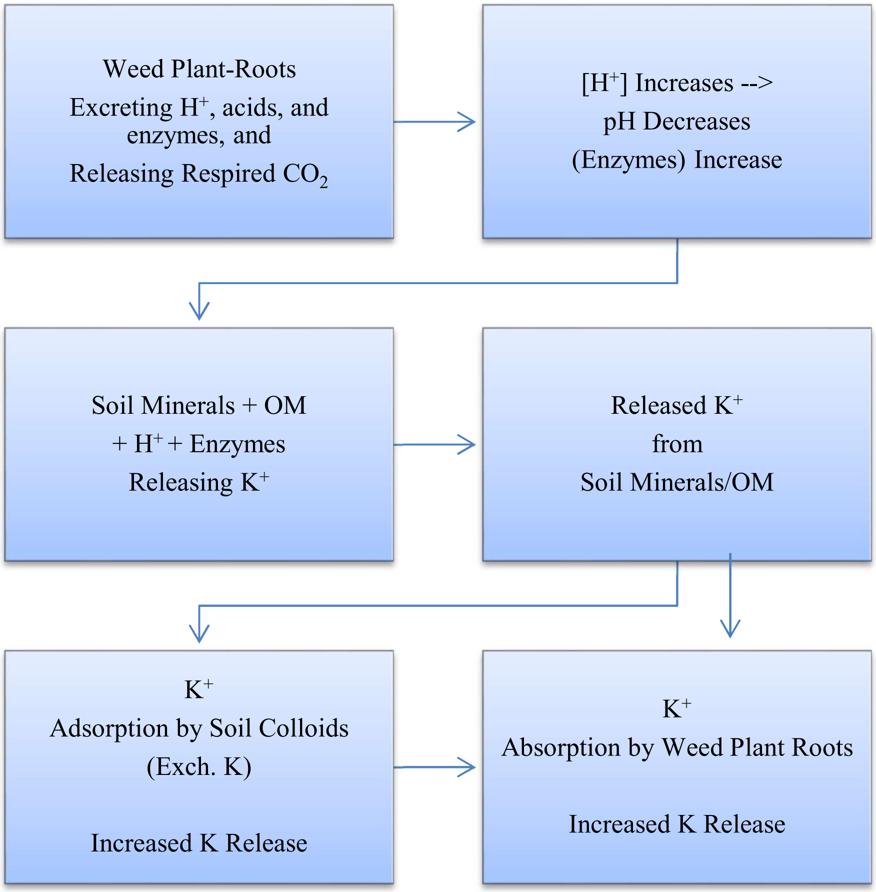

FIGURE 2. The conceptual relationship between excreted H^+, respired CO_2, and enxymes by plant roots, released K^+ from soil minerals and organic matter, and improvement of plant growth (after [10])

The effect of roots excretion of organic acids and respired CO_2 was also probable. The increase in the soil H^+ concentration is probably the summation of the effect of organic acids excreted by plant roots and also the H^+ generated by the reaction of the respired CO_2 and soil H_2O. The effect of excreted enzymes by weed roots and microorganism activities related to plant roots was also probable, but this data is insufficient to explain this phenomenon.

However, the higher RSR of *A. pintoi* as compared to other weeds may partially explain this phenomenon (**Table 6**). The RSR of *A. pintoi*, ranging from 0.521-to 1.220, was significantly higher than the other four weeds 0.125-0.690. The RSR of *A. pintoi* in subsoils were in general with a few exceptions higher than those in topsoils. These data may have also caused the higher soil enzymes caused by *A. pintoi* and produced more organic K through soil organic matter enzymatic decomposition. The high correlation of the relative changes in the soil available K and the weed root dry-weight may suggest that the relative soil available K was fairly affected by weed roots and the soil properties related to weed roots.

The ability of weed roots to explore the soil mineral K is related to the values of root-to-shoot ratios (RSR). *A. pintoi*, that was shown to induce the highest relative change in the available K (**Table 5**), was found to have the highest RSR among the weeds employed in this research. The RSR of *A. pintoi* in topsoil of Jabung was more than twice compared to those of *A. gangetica* and *Widelia sp.* and almost 1.5 times those of *P. conjugatum* and *P. purpureum*. A similar pattern was observed in soil of Tanjung Bintang. The higher portion of *A. pintoi* biomass as roots might have enabled this weed to explore more soil minerals and induced the release of more soil mineral K. The RSR values of weeds are also shown to be higher in the subsoils than those in the topsoils since weed plant roots must work harder in less fertile condition.

CONCLUSIONS

The soil available K was depleted by weeds except that in soils planted with *A. pintoi* as indicated by the positive Δ Avail. K [Δ Avail. K = Final Avail. K (After Planting) – Initial Avail. K (Before Planting)], suggesting that *A. Pintoi* root was more effective in stimulating the release of soil mineral and organic K. The effectiveness of weeds followed: *A. Pintoi* > *A. gangetica* > *Widelia sp*. > *P. conjugatum* > *P. purpureum.*

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