Laboratory Experiment on Soil Nutrients Mineralization and Interaction as Affected by Cocoa Pod Husk, Kola Pod Husk and Urea Fertilizer in Alfisol

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Citation

Abstract
Many researches have been conducted on the effect of cocoa pod ash, Kola pod husk and mineral fertilizers on yield of crops. However, little has been done on mineralization and interaction rates of these agro-wastes mixed with soil constituents. A laboratory incubation study was carried out to determine the mineralization and interaction rates of N, P, K, Mg, Ca and Na by kola pod husk (KPH), Cocoa pod husk (CPH) and urea fertilizer (100UF) mixed with soil collected from an Alfisol in Southwestern Nigeria. Kola pod husk (KPH) and CPH were applied at the rate of 0, 2.5 and 5g kg⁻¹. Urea fertilizer was applied at a rate of 0.05g kg⁻¹. The treatments were replicated nine times and arranged in a completely randomized design (CRD). The treatments were incubated for 30, 60 and 90 days. Soil pH, OC, N, P, K, Mg and Na were influenced by KPH, CPH and 100UF at different rates and periods. The exchange acidity was only reduced at 90 days of incubation. The mean percent base saturation for 0, 5CPH, 10CPH, 5KPH, 10KPH and 100UF were 80, 80, 84, 86, 90 and 79% respectively while the corresponding exchangeable sodium (ESP) were 13.7, 11.7, 9.4, 9.6, 9.6 and 9.6. The Ca: K interaction ranged from 3 - 8 after 90 days of incubation, while Ca: Na, Mg: K, Mg: Na and K: Na ranged from 1.6 – 8.6, 1.3 – 6, 1.3 – 5.3 and 0.8 – 3 respectively.

1. Introduction

Many studies have investigated the use of cocoa pod husk, kola pod husks and mineral fertilizers for soil fertility management[1, 2]. Cocoa pod husk is a by-product of *Theobroma cacao* while kola husk is the cover of kola nut that is removed and discarded. Kola nut is a seed derived from Kola tree (*Kola acuminata, Kola nitida or Kola coocoensis*). Cocoa pod husks and kola pod husks are very common in Nigeria. They are nuisance in cocoa and kolanut farms. Most of the studies investigating these agro-wastes tend to focus their attention on nutrient uptake and yield by crop neglecting the nutrients being released by the agro-wastes, how their nutrients interact with one another and their effects on soil, water, water bodies and the atmosphere in general. Some researchers have recommended up to 10 t ha⁻¹ or more of these agro-wastes for crop yield without considering the negative impacts on soil and water bodies. Records show that over - application of nitrogen supplying fertilizers may cause pollution of water and water...
bodies. For example, excess nitrate nitrogen pollutes drinkable water. The objectives of this study were to compare the rates of macro nutrients mineralization and their interactions in Ondo Southwestern Nigeria soil.

2. Materials and Methods

The laboratory incubation study was set up at the laboratory of Agricultural Science, Department of Adeyemi College of Education, Ondo. Soil samples were collected with an Auger from AladeIdanre, Ondo State, Nigeria. Surface soil samples (0 to 20cm) were randomly collected, bulked, air-dried and passed through a 2mm sieve.

2.1. Treatment Application

One kilogram of air-dried soil sample was weighed into 36 different plastic cups and labeled according to the treatment applied. The required amount of 0 (control), 2.5 and 5g for both cocoa pod husk and kola pod husk to represent 0, 5 and 10t ha\(^{-1}\) respectively were weighed into the plastic cups and replicated three times. Urea was applied at 0.05kg ha\(^{-1}\). Equal volume of water was added to each treatment throughout the ninety days incubation period. Destructive method was used for chemical analysis.

2.2. Soil Analysis

Soil pH was determined using a glass electrode pH meter in 1:2 soil water ratios. Ten (10)g of the soil sample was weighed into a 100ml beaker (in duplicate) and 200ml of distilled water was added, each beaker was stirred several times for 30 minutes. The pH of the samples was measured by immersing the glass electrode into the clear solution on top of the suspension; care was taken not to stir the suspension before taking the measurement.

Total N was determined by Microkjeldahl method. This involved distillation and titration. Available phosphorus (P) was extracted by the Bray-I-method. Two (2g) of air-dried soil sieved with 2mm diameter sieve was weighed into 250mm conical flask. 30ml of HClO\(_4\) was added and then digested on a hot plate in the fume cupboard at 130°C until solution became clear. 50ml of distilled water was added and filtered into 100ml standard flask and available P was determined colorimetrically.

Exchange bases (K, Ca, Mg and Na) were extracted with neutral ammonium acetate. Ten 10g air-dried soil sample sieved through a 2mm diameter sieve was weighed into a conical flask and 100ml of 1 mole ammonium acetate was added. Calcium, Mg, K and Na were determined from the filtrate by Atomic Absorption Spectrophotometer (AAS). Organic carbon was determined by the Walkkey Black wet oxidation method. This was carried out by weighing 1g of air-dried soil sample into a 250mm conical flask. 10ml of 0.167 molar potassium dichromate (vi) was added, 20ml of H\(_2\)SO\(_4\) was added and the flask swirled gently until the soil and reagent were thoroughly mixed. Consequently the flask was vigorously swirled for one minute and allowed to stand after which three drops of ferroin indicator were added. The solution was then titrated with 0.5 mole iron (ii) ammonium sulphate. The result of the titration was multiplied by 1.33 to give percentage organic carbon. The equation used to calculate exchange sodium percentage was ESP = Na X 100/CEC.

2.3. Data Analysis

Data collected were subjected to analysis of variance (ANOVA) using statistical analysis system institute package (SAS, 2000). Means were separated using Duncan’s Multiple Range Test (DMRT)

3. Results and Discussion

The soil was slightly acidic, low in N, P and fairly adequate in cations.

<table>
<thead>
<tr>
<th>Soil Properties</th>
<th>Soil Value</th>
<th>N (%)</th>
<th>P (%)</th>
<th>K (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ph</td>
<td>5.29</td>
<td>0.24</td>
<td>0.26</td>
<td>6.07</td>
</tr>
<tr>
<td>OC%</td>
<td>1.51</td>
<td>0.78</td>
<td>0.38</td>
<td>3.36</td>
</tr>
<tr>
<td>N%</td>
<td>0.14</td>
<td>0.13</td>
<td>0.13</td>
<td>3.36</td>
</tr>
<tr>
<td>P mg kg(^{-1})</td>
<td>5.27</td>
<td>1.91</td>
<td>1.91</td>
<td>3.36</td>
</tr>
<tr>
<td>K C mol kg(^{-1})</td>
<td>0.33</td>
<td>0.33</td>
<td>0.33</td>
<td>3.36</td>
</tr>
<tr>
<td>Ca C mol kg(^{-1})</td>
<td>1.27</td>
<td>1.27</td>
<td>1.27</td>
<td>3.36</td>
</tr>
<tr>
<td>Mg C mol kg(^{-1})</td>
<td>1.91</td>
<td>1.91</td>
<td>1.91</td>
<td>3.36</td>
</tr>
<tr>
<td>Exchange acidity C mol kg(^{-1})</td>
<td>0.13</td>
<td>0.13</td>
<td>0.13</td>
<td>3.36</td>
</tr>
</tbody>
</table>

3.1. Composition of Cocoa Pod Husk and Kola Pod Husk

Table 2 shows the chemical analysis of CPH. Cocoa pod husk (CPH) contains N, P and K. This corresponds with research conducted by Ajayi [3 and 4] showing that CPH contained plant nutrients such as N,P,K, Ca and Mg. Mensah[5], reported that application of raw CPH to soil improved plant nutrients such as N,P,K and Na. Ca and Mg. Adu-Dapach et al. [4] conducted an experiment in Ghana which showed that CPH contained reasonable amount of K. In a similar research conducted by Ayeni[2] indicated that CPH could be used as fertilizer.

The chemical analysis of KPH shows that it contains N, P and K. This is in line with research conducted by Makinde et al [6] that KPH contains reasonable amount of plant nutrients and carbon that could be used to improve the soil chemical and physical conditions. Makinde et al.,[6] reported that high carbon content is an added advantage to improve the low soil OC and to serve as a buffer to reduce the acidic condition of the soil.
3.2. Nutrient Mineralization by Cocoa Pod Husk, Kola Pod Husk and Urea Fertilizer at 30 Days

There were no significant differences in pH of the soil samples when KPH, CPH and 100UF were applied to the soil. However, the treatments seemed to increase soil pH compared to the control.

Only KPH at 10 t ha\(^{-1}\) significantly increased soil OC at 30 days of incubation. Compared with control, CPH significantly reduced total N while KPH at 10 t ha\(^{-1}\) significantly increased soil total N. Application of CPH at 10 t ha\(^{-1}\) and KPH at 5 t ha\(^{-1}\) significantly increased available P. The available P content due to the application of 5 t ha\(^{-1}\) CPH and 100UF were generally low. This might be as a result of very low P present in 5 t ha\(^{-1}\)CPH and the absence of P in urea fertilizer. The very low available P in the control experiment confirmed the assertion of Solomon and Lehmann\[6\] that Nigeria soils are generally low in P. The low P in Nigeria soils might occur as a result of low inherent soil P, depletion of soil P by crop removal, absorption and fixation of P with Fe and Al oxides and hydroxides \[6\]. The increase in available P by 10 t ha\(^{-1}\) CPH shows that P present in 5 t ha\(^{-1}\) CPH would be too low to release significant available P to the soil.

Only 100UF and 10 t ha-1KPH significantly increased total N. This might be as a result of high amount of N present in urea fertilizer and was easily released to the soil within one month of incubation. Urea fertilizer contains 46% of N. The N content in the agro-wastes used especially the CPH were generally low as seen in table 2. Kola pod husk (KPH) significantly increased Mg. compared with control; all the treatments significantly increased available Ca except 100UF. The increase in available Ca by KPH and CPH without significant increase in Ca by 100UF indicated that the Ca released to the soil was derived from KPH and CPH. Many researchers on KPH and CPH have shown that the agro-wastes contain high amount of Ca thus; are suitable as liming materials \[6\].All the treatments tended to reduce N compared to control. Only KPH rates had meaningful impact on soil Mg.

Addition of KPH and CPH to soil samples increased the CEC of the soil thus showing that the two agro-waste products could be used to increase plant nutrients where the soils are deficient of these nutrients. At 30 days of incubation, exchange acidity (EA) was increased with application of KPH and CPH contrary to the expectation that the agro-wastes would reduce the EA because of the high cation content. The residual acidity might have been converted to active acidity which might have led to insignificant change in the level of AE compared with control. The percent base saturation for 0, 5CPH, 10CPH, 5KPH, 10KPH and 100UF were 78, 84, 80, 83 and 76% respectively while the corresponding ESP were 15, 10, 10.4, 10, 10.6 and 12.5. The percent base saturation is normal for Alfisols so also the ESP at 30 days of incubation since the tolerable level of ESP is 16 or below.

### Table 3. Rate of release of major nutrients by cocoa pod husk and kola pod husk at 30 days.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>pH</th>
<th>OC</th>
<th>N</th>
<th>P (mg kg(^{-1}))</th>
<th>K (mg kg(^{-1}))</th>
<th>Mg (mg kg(^{-1}))</th>
<th>Ca (mg kg(^{-1}))</th>
<th>Na (mg kg(^{-1}))</th>
<th>H+Al (mol kg(^{-1}))</th>
<th>CEC</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1ha(^{-1})</td>
<td>5.21</td>
<td>1.66</td>
<td>0.14b</td>
<td>7.13</td>
<td>0.36</td>
<td>1.78</td>
<td>3.00</td>
<td>0.80</td>
<td>1.09</td>
<td>5.33</td>
</tr>
<tr>
<td>0.5ha(^{-1})</td>
<td>5.65</td>
<td>1.48</td>
<td>0.12b</td>
<td>6.91</td>
<td>0.40</td>
<td>1.74</td>
<td>3.00</td>
<td>0.70</td>
<td>1.10</td>
<td>7.02</td>
</tr>
<tr>
<td>0.1ha(^{-1})</td>
<td>5.47</td>
<td>1.67</td>
<td>0.13b</td>
<td>12.22</td>
<td>0.32</td>
<td>1.60</td>
<td>2.05</td>
<td>0.59</td>
<td>1.11</td>
<td>5.67</td>
</tr>
<tr>
<td>0.5ha(^{-1})</td>
<td>5.29</td>
<td>1.50</td>
<td>0.14b</td>
<td>10.26</td>
<td>0.32</td>
<td>1.91</td>
<td>2.65</td>
<td>0.64</td>
<td>1.13</td>
<td>6.55</td>
</tr>
<tr>
<td>0.1ha(^{-1})</td>
<td>5.59</td>
<td>1.86</td>
<td>0.15b</td>
<td>7.80</td>
<td>0.47</td>
<td>1.86</td>
<td>3.18</td>
<td>0.78</td>
<td>1.10</td>
<td>7.39</td>
</tr>
<tr>
<td>100UF</td>
<td>5.30</td>
<td>1.61</td>
<td>0.17a</td>
<td>7.16</td>
<td>0.36</td>
<td>1.51</td>
<td>1.22</td>
<td>0.61</td>
<td>1.18</td>
<td>4.88c</td>
</tr>
</tbody>
</table>

Means with the same letter are not significantly different at 5% using Duncan Multiple Range Test

3.3. Nutrient Mineralization by Cocoa Pod Husk, Kola Pod Husk and Urea Fertilizer at 60 Days

The effect of KPH and CPH on soil pH and OC were significant at 60 days of incubation contrary to what were obtained at 30 days of incubation. All the treatments significantly increased soil pH and OC except 100UF. There was significant increase in total N with application of 10 t ha\(^{-1}\) of KPH and CPH and 100UF at 60 days compared with the control whereas no significant increase in N was observed in any of the treatments at 30 days of incubation except 100UF. Ofori-Frimpong et al.\[8\] and Ayeni et al., (2008) concluded that CPH increased soil OC, N, K, Ca and Mg in southwest Nigeria. Moyin-Jesu\[9\] and Ayeni\[10\] also reported that agro-industrial waste such as CPH is effective in increasing soil N, P, K, Ca and Mg.

Only 10 t ha\(^{-1}\) KPH and 100UF significantly increased available P at 60 days of incubation. Reduction in available P was observed with the application of 5 and 10 t ha\(^{-1}\) CPH and 5 t ha\(^{-1}\) KPH at 60 days of incubation. This might be as a result of high Ca\(^{2+}\) and Mg\(^{2+}\) as could be seen by the increase in the amount of Ca\(^{2+}\) and Mg\(^{2+}\) released to the soil at 60 days of incubation compared with Ca\(^{2+}\) released at 30 days of incubation (Tables 3 and 4). Ogunlade et al.\[11\] reported that high Al\(^{3+}\) Concentration in soil negatively affects the availability of P. The P content of the soil might be negatively affected by high Al\(^{3+}\) concentration. Even though there was no evidence of high Al\(^{3+}\) concentration as seen in Table 3, all the Al\(^{3+}\) concentrations in the soil might not be extracted during soil analysis. The low available P obtained might also be explained as a result of the high Ca\(^{2+}\) content released to the soil by both CPH and KPH. Phosphorus availability is restricted by both low pH which causes Al – P and high pH.
which causes Ca – P. The pH obtained when KPH and CPH were added to the soil samples was tending to neutral which, if a little higher might tend to alkalinity leading to Ca- P complex. Compared with the control, all the treatments significantly increased available K, Mg, Ca and CEC (except 100UF). The percent base saturation for 0, 5CPH, 10CPH, 5KPH, 10KPH and 100UF were 82, 88, 91, 90, 89 and 82% respectively while the corresponding ESP were 14, 9, 7.4, 7, 8.3 and 12. The percent base saturation is normal for Alfisols so also the ESP at 60 days of incubation since the tolerable level of ESP is 16 or below.

Table 4. Rate of release of major nutrients by cocoa pod husk, kola pod husk and urea fertilizer at 60 days.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>pH</th>
<th>OC</th>
<th>N (%)</th>
<th>P (%)</th>
<th>K (%)</th>
<th>Mg (%)</th>
<th>Ca (%)</th>
<th>Na (%)</th>
<th>C mol kg⁻¹</th>
<th>CEC</th>
</tr>
</thead>
<tbody>
<tr>
<td>0tha⁻¹</td>
<td>5.43</td>
<td>1.65a</td>
<td>0.11b</td>
<td>6.92c</td>
<td>0.47c</td>
<td>1.08b</td>
<td>2.42d</td>
<td>0.81a</td>
<td>1.07a</td>
<td>5.85b</td>
</tr>
<tr>
<td>5tha⁻¹CPH</td>
<td>7.10</td>
<td>1.55b</td>
<td>0.13b</td>
<td>5.80d</td>
<td>0.96b</td>
<td>1.26ab</td>
<td>5.00bc</td>
<td>0.81a</td>
<td>1.06a</td>
<td>9.09b</td>
</tr>
<tr>
<td>10tha⁻¹CPH</td>
<td>6.80a</td>
<td>1.68a</td>
<td>0.17a</td>
<td>6.07d</td>
<td>1.03a</td>
<td>1.47a</td>
<td>7.77a</td>
<td>0.90a</td>
<td>1.05a</td>
<td>12.22a</td>
</tr>
<tr>
<td>5tha⁻¹KPH</td>
<td>7.63a</td>
<td>1.57b</td>
<td>0.14b</td>
<td>6.74c</td>
<td>1.02a</td>
<td>1.40a</td>
<td>6.01b</td>
<td>0.70a</td>
<td>1.06a</td>
<td>10.20a</td>
</tr>
<tr>
<td>10tha⁻¹KPH</td>
<td>6.26b</td>
<td>1.87a</td>
<td>0.16ab</td>
<td>7.29a</td>
<td>0.87b</td>
<td>1.52a</td>
<td>5.17a</td>
<td>0.77a</td>
<td>1.07a</td>
<td>9.30a</td>
</tr>
<tr>
<td>100UF</td>
<td>6.63b</td>
<td>1.35d</td>
<td>0.19a</td>
<td>7.23a</td>
<td>1.08a</td>
<td>1.17b</td>
<td>3.01d</td>
<td>0.69a</td>
<td>1.07a</td>
<td>5.85b</td>
</tr>
</tbody>
</table>

Means with the same letter are not significantly different at 5% using Duncan Multiple Range Test

CPH-Cocoa pod husk, KPH - Kola pod husk, UF-Urea fertilizer

3.4. Nutrient Mineralization by Cocoa Pod Husk, Kola Pod Husk and Urea Fertilizer at 90 Days

Compared with the control, application of KPH and CPH significantly increased soil pH, OC, total N and K at 90 days of incubation. It was observed that 10tha⁻¹ CPH and KPH significantly increased soil available P. It was observed that total N was reduced with application of 100UF at 60 days compared with 90 days of incubation. This might be as a result of volatilization of N. The nitrate nitrogen might have been converted to nitrogen (iv) oxide and escaped into the atmosphere. The effect of KPH and CPH on soil EA was manifested at 90 days of incubation. Generally, Mg and Na increased at 90 days of incubation compared with 60 days while Ca and EA reduced at 90 days of incubation compared with 60 days. The percent base saturation for 0, 5CPH, 10CPH, 5KPH, 10KPH and 100UF were 82, 70, 80, 85, 98 and 79% respectively while their corresponding ESP were 12, 16, 11.5, 11.9, 10 and 9. The percent base saturation is normal for Alfisols so also the ESP at 90 days of incubation since the tolerable level of ESP is 16 or below.

Table 5. Nutrient mineralization by cocoa pod husk, kola pod husk and urea at 90 days.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>pH</th>
<th>OC</th>
<th>N (%)</th>
<th>P (%)</th>
<th>K (%)</th>
<th>Mg (%)</th>
<th>Ca (%)</th>
<th>Na (%)</th>
<th>H Al C mol kg⁻¹</th>
<th>CEC</th>
</tr>
</thead>
<tbody>
<tr>
<td>0tha⁻¹</td>
<td>5.23c</td>
<td>0.16b</td>
<td>1.13b</td>
<td>7.58c</td>
<td>0.34b</td>
<td>1.07c</td>
<td>2.30d</td>
<td>1.34ab</td>
<td>1.06a</td>
<td>5.8c</td>
</tr>
<tr>
<td>5tha⁻¹CPH</td>
<td>6.76ab</td>
<td>0.15b</td>
<td>1.35a</td>
<td>6.61d</td>
<td>0.47b</td>
<td>1.51b</td>
<td>5.04c</td>
<td>1.30b</td>
<td>1.12a</td>
<td>8.32b</td>
</tr>
<tr>
<td>10tha⁻¹CPH</td>
<td>6.80a</td>
<td>0.17b</td>
<td>1.31a</td>
<td>10.10ab</td>
<td>0.47b</td>
<td>1.93b</td>
<td>5.79b</td>
<td>1.21b</td>
<td>1.14a</td>
<td>10.54a</td>
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<td>5tha⁻¹KPH</td>
<td>6.01b</td>
<td>0.19a</td>
<td>1.38a</td>
<td>7.70c</td>
<td>0.56a</td>
<td>2.98a</td>
<td>3.38d</td>
<td>1.08c</td>
<td>1.09a</td>
<td>9.10b</td>
</tr>
<tr>
<td>10tha⁻¹KPH</td>
<td>6.92a</td>
<td>0.17ab</td>
<td>1.30a</td>
<td>10.86a</td>
<td>0.55a</td>
<td>1.89b</td>
<td>6.22a</td>
<td>1.12a</td>
<td>1.12a</td>
<td>10.98a</td>
</tr>
<tr>
<td>100UF</td>
<td>5.09c</td>
<td>0.16b</td>
<td>1.25ab</td>
<td>8.06b</td>
<td>0.42b</td>
<td>1.09c</td>
<td>3.10d</td>
<td>0.50d</td>
<td>1.15a</td>
<td>5.42c</td>
</tr>
</tbody>
</table>

Means with the same letter are not significantly different at 5% using Duncan Multiple Range Test

CPH-Cocoa pod husk, KPH-Kola pod husk, UF-Urea fertilizer

3.5. Nutrient Interaction

Tables 6, 7 and 8 show the interactions among nutrients when fertilized with KPH and CPH at 30, 60 and 90 days of incubation. The Ca: Mg ratio of all the treatments ranged between 1.3 – 1.9 indicating that Ca: Mg interaction is still normal for nutrients release especially P. Reports have shown that high amount of Mg antagonizes P. Abdod [12] and Esmail et al.[13] asserted that increase in Mg: Ca to 1.5 in soil solution and irrigation water caused a significant increase in available P in the soil and its recovery by plants. Several researches have shown that the ratio of exchangeable Ca and Mg for normal crop growth is 1-20. Adetunji [14] affirmed that Ca:Mg ratio of 1.2 might not produce Mg deficiency.

The Ca: K interaction falls between 3 -8 at 30, 60 and 90 days of incubation. Several researches have shown that ideal ratio of Ca:K is 1-13, while 14 and above might lead to nutrient antagonism. Ayeni and Adeleye,[15] noted that availability of one nutrient element normally hinders the availability of the other element if not in balanced proportion. The interactions of Ca:Na, Mg:K, Mg:Na and K:Na ranged between 1.6 – 8.6, 1.3 – 6, 1.3 – 5.3 and 0.8 – 3 respectively. The nutrients are still in balanced proportion. This is in line with the previous research conducted by Ayeni and Adeleye, [15] and Ogunlade et al. [11] who reported that organic manures whose Ca:Mg ratio range between 1-10 enhance mineralization and ratio greater than 1:30 in organic wastes cause immobilization.

Ujwalara and Ade [16] reported that excessive amounts of nitrogen negatively affect P, K, Fe and almost all secondary and micro nutrients like Ca, Mg, Fe, Mn, Zn and Cu.
Improper amount of nutrients in the soil can affect plant nutrients uptake. For example, Keltjens and Tan [17] found that Mg was more efficient in alleviating Al toxicity in monocots, while Ca was more effective in the dicots. More specifically in soybean, low concentration of Mg is as also increase the uptake rates of Mg and also K by plants. Reported increased in Ca concentration to a certain level will also increase the uptake rates of Mg and also K by plants. Gransee and Fuhrs [18] effective as higher concentration of Ca, but in wheat no such difference between cations is evident. Improper amount of nutrients in the soil can affect plant nutrients uptake. For example, Keltjens and Tan [17] found that Mg was more efficient in alleviating Al toxicity in monocots, while Ca was more effective in the dicots. More specifically in soybean, low concentration of Mg is as also increase the uptake rates of Mg and also K by plants. 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