Potassium Thermodynamics as Affected by Irrigation, Organic and Inorganic Amendments in an Eutric Cambisol Sown to Maize in Kano, Nigeria

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ABSTRACT

A Trial under irrigation was conducted at Kano, Nigeria to evaluate the effects of irrigation and soil amendment type on K thermodynamics in Maize field. Split plot design was used with a factorial arrangement of 12 treatments in 3 m x 2 m plots. The experimental factors were irrigation intervals at 3 days (I3), 5 days (I5) and 7 days (I7); and soil amendments (5 tha-1 equivalent of Biochar or Compost; NPK at the equivalent of 120:60:60 and Control. Bulk soil (root-free soil) was sampled at seedling and tasseling between maize stands and subjected to analyses. K thermodynamics were determined using Quantity/Intensity approach. Linear curves with high significant correlation coefficient values (r = 0.98 – 0.99) were obtained from the Q/I experiment which is an indicator of the less significant role that high K affinity sites have in K exchange in the amended soils. The effect of the soil amendments on K Q/I parameters such as labile K, ARKe, PBCK, and pF were varied but statistically significant at 5% level of significance. The effect of irrigation interval, was varied but not statistically significant. The results portrayed the potency of especially organic soil amendments to enhance K availability and exchange within a season.

Key words: Amendments, Irrigation, Potassium, Soil, Thermodynamics

INTRODUCTION

There is highly variable plant available forms of K in many Nigeria’s soils (Idigbor et al., 2009). In the savanna regions of Nigeria, predominated by eutric cambisol, K is almost always the least of the basic cations in cultivated fields. This is despite its importance as a plant nutrient because of its unique role in maintaining ionic balance in the cytoplasm (Tisdale et al, 2003). An important arable crop in Nigeria across ecological divides, is maize which is extremely sensitive to soil K fertility. A mature maize crop can contain up to 300 kg K/ha in aboveground plant material (Abrishamkesh et al., 2015). The savannas of Nigeria are probably the dominant maize-producing zones of the country. These regions are also characterized by unpredictable rainfall pattern (Ojanuga, 2006) which makes irrigation a very common practice in the region supporting several crops end extending the production season.

There are four basic forms of K in the soil; solution, exchangeable, non-exchangeable and structural in soil mineral all of which are dynamically in equilibrium (Havlin et al., 2004; Idigbor et al., 2009). The Water soluble, exchangeable and non-exchangeable forms of K have been used to determine the K supplying capacity of soil by employing the quantity/intensity (Q/I) relationship (Beckett, 1964). The intensity factor is related to the concentration of K in the soil solution while the quantity factor is related to the adsorbed K in the exchange complex (Idigbor et al., 2009).

Quantity-Intensity studies to predict K availability (Jalali 2011; Najafi-Ghiri, 2014) have shown that several soil, agronomic and ecological factors may affect K release rate from soils. Among such agronomic factors are moisture availability and the use of soil amendments to improve soil nutrients supplying capacity. Organic soil amendments such as compost and biochar have been successfully used for the improvement of soils’ physical, chemical and biological properties thereby increasing crop yield (Kamali et al., 2010; Kalantari et al., 2011; Nada et al., 2011); while the use of inorganic fertilizers is a common practice in both research and production fields.
There is a plethora of literature on K dynamics in Nigeria’s soils across several ecological zones in relation to specific factors (Agbenin and Yakubu, 2006; Taiwo et al., 2009; Idigbor et al., 2009). Most literature however failed short of evaluating the influence of inducing moisture stress by varying irrigation time. Soil amendments (especially organic) that are currently gaining recognition for their multiple advantages as farm inputs and their environmental-friendliness are often also neglected by such studies.

The aim in this research therefore was to evaluate and compare under sown field conditions, the effect of variable irrigation period and soil amendment type on K thermodynamics using Q/I variables.

**MATERIALS AND METHOD**

**Experimental Location**
The research was based on field trial under irrigation in the dry season of 2015 within the months of February to May. It was conducted at the Research Farm of Faculty of Agriculture, Bayero University Kano between latitude 10 – 13° N and longitude 8 – 9° E. It is in the dry, sub-humid agro-ecological zone of Nigeria (Ojanuga 2006). The geology is basement complex (KNARDA (Kano Agricultural and Rural Development Agency) 1998) commonly producing Eutric Cambisol as the dominant soil type (FDLAR: Federal Department of Agriculture and Land Resources, 1991).

**Experimental Materials**
Two forms of organic amendments were used in this research; biochar and compost. Biochar was made from biomass largely composed of dried and threshed maize cobs in a fabricated pyrolysis kiln which was filled to ¾ of its volume and heated to about 400°C for 3 hours (Lehmann, 2007). Compost was produced in compost pens using anaerobically digested municipal solid waste (MSW); dried and fresh herbages and poultry litter (approximately 22.6 C:N). The system was periodically moistened with about a liter of water to about 5 kg of material at 5 – 7 days interval after the first 10 days. Periodic turning at approximately 2 weeks interval was done and the system was maintained for 2 months. The compost was cured for one week under shade. NPK and Urea were sourced locally from vendors in the city. Maize variety (2009 EVDT) was used as the test crop.

**Plot Size and Experimental Design**
The field was laid out in a split plot design with a factorial arrangement of 12 treatment combinations in plots measuring 3 m x 2 m. The experimental factors were irrigation intervals at 3 days (13), 5 days (15) and 7 days (17); and soil amendments (5 tha⁻¹ equivalent of Biochar and Compost; NPK at the rate of 120:60:60 ha⁻¹ and Control. These were laid out with the irrigation intervals as main plot and the amendments in the sub plot. The treatments were replicated three times making a total of 36 plots.

**Agronomic Practices**
Hoes were used to hand prepare the land before application of amendments and planting. Biochar and Compost were incorporated in the soil to the of depth 0-15 cm two weeks before planting. NPK (15:15:15) fertilizer was banded on the side of the plant at the rate of 60:60:60 kg/ha at 2 weeks after sowing (WAS) and urea (46% N) was used to supply the remaining 60kgN/ha at six weeks after planting. The maize was sown at the rate of two seeds per hill at a spacing of 25 x 75 cm, resulting in 4 maize rows per plot. Thinning to one plant per hill was done at 3 weeks after planting. Recommended cultural practices for maize such as weeding, pest and disease control were carried out in all plots.

**Soil Sampling and Preparation**
Soil samples were collected randomly from five locations of entire experimental field at a depth of 20 cm before the application of the amendments for characterization. Three composite samples were made from the above collected samples. Bulk soil (root-free soil) was sampled at seedling and tasseling stages between maize stands. 36 samples were collected at each sampling time. All soil samples were air-dried, crushed gently and sieved through a 2 mm sieve.

**Laboratory Analysis**
Compost and biochar were analyzed for total organic carbon (OC) by the dry combustion method at 540 °C for 4 h (Abad et al., 2002) and total N (TN) by Kjeldahl digestion (Bremmer and Mulvaney, 1982). Electrical conductivity and pH were analyzed in a 1:5 (w/v) water extract using a glass electrode (McLaughlin, 2009). Available Ca, Na, K and Mg and CEC were extracted with ammonium acetate (pH = 7) (Soil Survey Staff, USDA, 1975). Total P and K were determined after ashing. P was determined colorimetrically (Murphy and Riley, 1962). Ca, Na, K were determined with AAS while total K was analyzed using flame photometer. Amendments’ porosity was determined as described by Richard et al., (2002). Volatile matter (biochar) was separated at 450 °C for 30 minutes while ash matter was separated 500-550 °C sequentially (McLaughlin, 2009). Moisture content was measured by drying at 105 °C (compost) and 200 °C (biochar) for approximately 24 h while bulk density, particle density and water holding capacity were determined as described by Ahn et al. (2008). All laboratory analyses were done in triplicates and reported on a dry-weight basis.

Soil particle size determination was done using hygrometer, pH was determined in 1: 2.5 soil/water ratio with a pH meter. Organic carbon was determined by the wet oxidation.
method as described by Nelson and Sommers (1996), total nitrogen was determined by Kjeldahl digestion (Bremmer and Mulvaney, 1982) and exchangeable bases (Na, Mg, K, and Ca) of the soil samples were determined by the neutral ammonium acetate procedure (Anderson and Ingram, 1993). EC of the soil was determined in 1:2 soil–water ratio using conductivity meter. Exchangeable acidity of the soil samples was determined by the Bray 1 method as described by Jackson (1979). Effective cation exchange capacity of the soil samples was obtained by the summation of exchangeable Ca, K, Mg Na, and acidity.

**Quantity/Intensity relations determinations**

Quantity-Intensity experiments were based on the method of Beckett (1964). 5 g of soil sample from each treatment was treated with 50 ml concentration of 0.01 M CaCl₂ containing a range of potassium concentration from 0 to 0.01 M KCl. The suspensions of soil: solution (1:10) were shaken for 3 hours and left to stand for 24 hours for equilibrium, then suspensions were centrifuged and filtered. Ca, Mg and K in the filtrates were determined by atomic absorption spectrometry (AAS).

The change in the amount of exchangeable K (ΔK) which represents the quantity factor was calculated from the differences of concentrations of K in prepared solutions and equilibrated solutions. The potassium activity ratio (ARₖ), which represents the intensity factor, was calculated from the activities of potassium (aₖ), calcium (aₖᵃ) and magnesium (a₅₆) in the equilibrated solutions.

**Thermodynamics Measurements and Calculations**

K thermodynamic parameters were determined as follows;

**Ionic activity:** Ionic activity (a) of potassium, calcium and magnesium in the soil extracts was calculated as product of concentration of ions by their activity coefficient (y) values (Spark, 2003).

\[ a = y \cdot C \]

Where: y = activity coefficient, C = concentration of ions

**Activity coefficient:** Ionic activity coefficients were calculated using extended Debye-Huckel equation as follows (Spark, 2003):

\[ \log \gamma = -AZ_i^2 \sqrt{\frac{\mu}{1 + \alpha_i \beta \sqrt{\mu}}} \]

Where: \( Z_i \) = valency of ion, \( \mu \) = Ionic strength in mol/L,
\( A = 0.508 \) for water at 298 Kelvin \( \beta = 0.33 \) for water at 298 Kelvin and

\( \alpha_i \) = effective diameter of the ion = 0.30, 0.60 and 0.80 nm for \( K^+ \), \( Ca^{2+} \) and \( Mg^{2+} \) respectively.

**Ionic strength:** Ionic strength (\( \mu \)) mol/L was calculated by the formula of Griffin and Jurinak (1973):

\[ \mu = 0.0129 \cdot EC \]

Where: EC = Electrical conductivity

**Activity ratio of K:** Activity ratio of K (ARₖ) was calculated by the following formula of Diatta et al (2006):

\[ AR_k = \frac{a_k}{\sqrt{a_{Ca} + a_{Mg}}} \]

Where: (a) = activity in mol/L

**Free energy of replacement:** Free energy of replacement (F) was calculated from the equation shown below (Beckett, 1972):

\[ F = 2.303RT \log \frac{a_k}{\sqrt{a_{Ca} + a_{Mg}}} \]

Where: R = gas constant, T = absolute temperature

**K – selectivity coefficient (kG)**

The kG was calculated based on the following equation as adapted in Diatta et al. (2006):

\[ kG = \frac{K_{ex}^{(Ca + Mg)}_{ex}}{\gamma (Ca + Mg)_{aqy}^{ex}} \]

Which by rearrangement yields the following:

\[ kG = \frac{K_{ex}^{(Ca + Mg)}_{ex}}{\gamma (Ca + Mg)_{aqy}^{ex}} \times \frac{\sqrt{\gamma (Ca + Mg)_{aqy}^{ex}}}{\gamma K_{aqy}} \]

The ratio \( K_{ex}^{(Ca + Mg)}_{ex} \) describes the relative specificity of non-Coulombic forces on colloid surfaces for K and expresses the preference factor \( P_{(Ca + Mg)}^{kex}_{ex} \). Higher values are indicative of increased preference for K over Ca and Mg, and vice versa.

**Statistical Analysis**

Analysis of variance was performed with the GenStat Discovery Edition Version 4. Differences between the K
Quantity/Intensity parameters obtained were separated using Tukey test at 5 % level of probability.

RESULTS AND DISCUSSIONS

Characteristics of Organic Amendments
The properties of the organic amendments (Table 1) showed both materials to be light, porous and dry, with higher water content in compost. Particle density of compost was more than 3 times that of the biochar while bulk density of compost was approximately 4 times that of biochar. It is important to note that water holding capacity of biochar was approximately 30 times more than that of the compost amendment.

The variabilities in the physical and chemical properties of both materials were believed to influence the soil responses after amendment. Compared to the compost, from the point of view of the result here, it is obvious that biochar is likely more important as a soil conditioner and driver of nutrient transformations and less so as a primary source of nutrients as was highlighted by Lehmann et al., (2011).

Description of the Experimental Soil
The properties of the experimental soil are presented in Table 2. The soil was non saline, close to neutral and sandy loam in texture. Percent K saturation of 5.07% is indicative of a good potassium status of the soil. The high value of K- activity (0.9750) coefficient indicates that the majority of potassium ions exist in active form in soil solution given the low ionic strength (0.00259 mol.L⁻¹). The value of free energy of replacement, - ΔF (-2629 cal.mol⁻¹) shows that the experimental soil has medium supplying power of K. The soil with its low to medium values for most parameters is generally of marginal fertility (Uzoho et al, 2007).

Effects of Amendments on Q/I Relationship
Activity ratio values in the equilibrium solutions were plotted against the values of change in exchangeable K, and the best fit linear curves with high significant correlation coefficient values (r = 0.98 – 0.99) were selected (Figures 1a – x).

The high significant linear relationships in this study is in conformity with the Gapon equation. The linearity of the Q/I curves is an indicator of the less significant role that high K affinity sites have in K exchange in the amended soils. As proposed by Evangelou and Blevins (1988) the linearity is due to ion exchange on an infinite planar surface, which describes exchange at a much larger number of sites with a less specific affinity for K. The buffer capacity of the soil then depends greatly on exchange with low affinity sites likely from organic matter.

Linear Q/I curves have been described in other findings (Evangelou and Blevins, 1988) who stated further that curvilinearity may not always be expected, with high loads of exchangeable monovalent cations as may be provided by addition of organic amendments (Haynes and Williams, 1993). The vertical intercepts of all the curves were below (0-0) line which is an indicator that K will be available under the existing Ca and Mg conditions.

Effect of Amendments on K Quantity-Intensity Parameters
The effect of the soil amendments on K quantity-intensity parameters are presented in Table 3.

Effect on labile potassium (KL)
This is a measure of the reserves of available K. Generally, addition of soil amendments caused an increase in KL values compared to the control. This indicates that the amended soils may have higher K⁺ ion strength in comparison to Ca²⁺ and Mg²⁺ which potents immediate availability of K. The higher labile K at seedling in NPK treatment is an indicator that K ions in NPK treatment are more readily available than in biochar and compost. Higher biochar adsorption sites capable of ion exchange could have caused the higher values in this treatment at tasseling. The tendency for ions to be readily available for crop uptake and leaching in NPK treated soil could have caused the decreased value at tasseling in comparison to the organic amendments that could have high adsorption sites capable of ion exchange. This is agreement with the findings of Wang et al, (2004).

Effect on equilibrium potassium activity ratio (AR Ke)
AR Ke represents the degree of K absorption or intensity by plants from the soil. The values were fairly low in different amendments but were all however higher than the control. This may be because of the higher concentrations of both Ca⁺⁺ and Mg⁺⁺ in the soil (Table 2) as explained by Diatta et al. (2006) who showed that significantly higher share of Ca⁺⁺ and Mg⁺⁺ in the ECEC may cause relatively low AR Ke values. The apparent implication of these low values is that low concentration of K in solution may be expected at equilibrium. There was an apparent gain with amendments addition in relation to AR Ke at seedling because of their relatively high K content (Table 1). The decreased value observed at tasseling may be due to intensive uptake by the crop. This agrees with Fergus et al. (1972) who reported that intensity of soil K decreased in soils with cropping conditions which may result in marked K depletion.

Effect on potential buffering capacity (PBC Ke)
PBC Ke measures the ability of the soil to maintain intensity of K at equilibrium as plants uptake and/or leaching are taking place (Wang et al., 2004). Result here suggests that PBC Ke changes with amendments and sampling times. All the treatments had higher PBC Ke values than the control. The greater capacity of the biochar and compost amended soils at seedling to maintain K concentration for longer periods are clearly portrayed as compared to the NPK treatment.
Table 1: Physical and chemical properties of the organic amendments

Mat. = Material, BC = Biochar, CP = Compost, BD = Bulk Density, PD = Particle Density, Por. = Porosity, MC = Moisture Content, WCH = Water Holding

| Mat. | BD (kg/m³) | PD (kg/m³) | Por. (%) | MC (%) | WHC (g/kg) | MM (%) | AM (%) | FM (%) | pH | EC (ds/m³) | CEC (Cmol/kg) | OC (%) | TN (g/kg) | CN | TP (mg/kg) | TK (mg/kg) | Ca (Cmol/kg) | Mg (Cmol/kg) | K (Cmol/kg) | Na (Cmol/kg) | KSP (%) |
|------|-------------|-------------|----------|--------|------------|--------|--------|--------|----|-----------|-------------|--------|----------|---|-----------|-----------|-------------|-------------|-------------|-------------|---------|--------|
| BC   | 0.21        | 0.68        | 87.5     | 1.04   | 73.1       | 15.5   | 2.3    | 82.5   | 7.6| 0.37      | 18.7        | 75.3   | 10.1     | 74.5 | 24.4      | 16.4      | 0.5         | 1.25       | 0.897      | 0.012       | 4.8     |
| CP   | 0.81        | 2.52        | 49.1     | 26.3   | 2.44       | 18     | 29.5   | 52.5   | 6.5| 3.67      | 23.07       | 28.8   | 12.8     | 22.5 | 34.9      | 21.3      | 0.5         | 1.21       | 1.077      | 0.019       | 4.67    |

Capacity, MM = Mobile Material, AM = Ash Material, FM = Fixed Material, TN = Total N, TP = Total P, TK = Total K, KSP = K saturation percentage

Table 2: Physical and chemical properties of the experimental soil before treatment

<table>
<thead>
<tr>
<th>Sand (%)</th>
<th>Silt (%)</th>
<th>Clay (%)</th>
<th>Texture</th>
<th>pH</th>
<th>EC (ds/m³)</th>
<th>ECEC (Cmol/kg)</th>
<th>OC (%)</th>
<th>N (%)</th>
<th>Av.P (mg/kg)</th>
<th>EA (mg/kg)</th>
<th>Ca (cmol/kg)</th>
<th>Mg (cmol/kg)</th>
<th>K (cmol/kg)</th>
<th>Na (cmol/kg)</th>
<th>KSP (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>67.9</td>
<td>20.4</td>
<td>11.7</td>
<td>Sandy loam</td>
<td>6.58</td>
<td>0.2</td>
<td>4.167</td>
<td>1.31</td>
<td>0.16</td>
<td>4.13</td>
<td>0.167</td>
<td>2.1</td>
<td>1.63</td>
<td>0.211</td>
<td>0.077</td>
<td>5.07</td>
</tr>
</tbody>
</table>

K-Thermodynamics Parameters

\[
\mu \text{ mol.L}^{-1} \quad \Upsilon \quad K_a \text{ mol.L}^{-1} \quad ARK \text{ mol.L}^{-1} \quad -\Delta G \text{ Cal.mol}^{-1} \\
\begin{align*}
0.00259 & \quad 0.975 & \quad 0.00206 & \quad 0.01286 & \quad -2578
\end{align*}
\]

Av.P = Available P, EA = Exchangeable acidity, KSP = K saturation percentage, \( \mu \) = Ionic strength, \( \Upsilon \) = Activity coefficient, \( K_a \) = K activity, \( ARK \) = Activity ratio of K. \( -\Delta G \) = Free energy of replacement
Table 3: Potassium Quantity – Intensity parameters of the soils

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Seedling Stage</th>
<th>Tasseling Stage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>-ΔGK (Cal mol⁻¹)</td>
<td>pF</td>
</tr>
<tr>
<td>Amendmenst</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Biochar</td>
<td>-3415a</td>
<td>0.12</td>
</tr>
<tr>
<td>Compost</td>
<td>-3339a</td>
<td>0.124</td>
</tr>
<tr>
<td>NPK</td>
<td>-3337a</td>
<td>0.284</td>
</tr>
<tr>
<td>Control</td>
<td>-3766b</td>
<td>0.098</td>
</tr>
<tr>
<td>SED±</td>
<td>3.28</td>
<td>0.003</td>
</tr>
<tr>
<td>Irrigation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>I3</td>
<td>-3446a</td>
<td>0.155</td>
</tr>
<tr>
<td>I5</td>
<td>-3412b</td>
<td>0.15</td>
</tr>
<tr>
<td>I7</td>
<td>-3373a</td>
<td>0.164</td>
</tr>
<tr>
<td>SED±</td>
<td>2.55</td>
<td>0.002</td>
</tr>
</tbody>
</table>

ARKe = equilibrium activity ratio of potassium, PBCK = potential buffering capacity of potassium, KL = labile potassium or equilibrium exchangeable potassium, -ΔG = free energy, pF = preferential factor, kG = Gapon selectivity coefficient. Means in a column followed by the same letter(s) are not significantly different at 5% level of probability using Turkey Test.
The values of PBC\textsubscript{K} in comparison to the AR\textsubscript{Keq} in different amendments clearly show that the higher the equilibrium potassium activity in the soil solution, the relatively lower the soil buffering capacity and inversely. The higher values of K-buffering capacity indicate that the soil has high ability to resist changes in potassium during the cropping season. According to Wang et al., (2004), high PBC\textsubscript{K} values are a measure of constant availability of K in the soil solution over a long period and the less need for frequent K fertilization. Accordingly, soils amended with biochar or compost have a potential to compensate the reduction in potassium level observed from NPK amended soil during a cropping season.

**Effect on free energy of potassium replenishment at equilibrium (\(-\Delta G^{Keq}\))**

The free energy of K replenishment classifies the supplying power of potassium in soils (Woodruff, 1955). The different classes of \(-\Delta G^{Keq}\) reported by Woodruff are presented in Table 4. Accordingly, soils with lower than \(-3500\) cal.mol\(^{-1}\) have poor supplying power of K and those with \(-3500\) to \(-2000\) cal.mol\(^{-1}\) have medium supplying power of K. Soils with greater than \(-2000\) cal.mol\(^{-1}\) are considered as high in K supplying power.

It can be deduced that application of biochar is able to increase the activity of K in soil solution resulting in the increase in availability of K in soils. This is probably due to its higher potency to retain moisture and the fact that biochar is a negatively charged material and could increase K adsorption sites (Liang et al. 2006). From the result here it can also be seen that though compost and NPK amended soils may have higher available K content, but the unfavourable exchange energy indicates that plants may have to exert more energy to get K from the soil at tasseling. The higher \(-\Delta G\) value in the control across growth stages is indicative of poor availability of K relative to other cations especially Ca and Mg, in agreement with the background values in Table 2.

**Effect on Gapon selectivity coefficient (kG) and preferential factor (pK)**

The kG value expresses the relative affinity soils may have for K in the presence of Ca and Mg both in the soil solid phase and soil solution under equilibrium conditions. The results are suggestive of the fact that the relative affinity for K was similar for organic amendments at seedling. The result also indicates the relative maintenance of similar affinity for NPK treatment at both sampling times. These observations agree with Diatta et al. (2006) who observed that changes in kG values are basically attributable to the levels of exchangeable Ca and Mg. The result also revealed higher K selectivity coefficient for NPK treatment than the organically amended soils across sampling times. This may be due to the lower (monovalent) selectivity coefficient of organic matter (Salmon, 1964).

**Effect of Irrigation Intervals on K Quantity-Intensity Parameters**

The effect of irrigation intervals on the various K quantity-intensity parameters are also presented in Table 3. There were significant variations among the three irrigation levels at 5% level of significance.

**Effect of irrigation on labile K (KL) and activity ratio (AR\textsubscript{Keq})**

The labile K (KL) responded insignificantly with different intervals of irrigation and ranged from. There was however significant variation among AR\textsubscript{Keq}'s with irrigation interval. Increasing irrigation frequency from 17 to 15 then to 13 factorially raised the AR\textsubscript{Keq} values indicating the tendency for K mobility to be affected by soil moisture stress imposed by the irrigation intervals.

**Effect of irrigation on potassium buffering capacity (PBC\textsubscript{K})**

PBC\textsubscript{K} didn’t differ significantly in the studied soils, with different intervals of irrigation. The slightly higher value at I3 however shows an increased K maintaining power with increasing water availability.

**Effect of irrigation on free energy (\(-\Delta G^{Keq}\)) and selectivity coefficient (kG)**

The value of free energy of K replacement under the different intervals of irrigation was within the range for medium supplying power of K at seedling while at tasseling the values were within the poor K supplying range (Table 4). Similar to the effect of the amendments, the soils under different irrigation interval exhibited quite similar preference for potassium. These results may explain the observation of Barber (1978) that crop response to K fertilization in dry seasons often differs from that of wet seasons.

**CONCLUSION**

Findings here have revealed the potency of short term gain in soil K availability and exchange through the use of soil amendments, especially organic materials such as compost and biochar, which throughout have positively enhanced the solubility and exchange related parameters. Although irrigation did not have a significant effect on the K thermodynamics, the variable responses of the parameters to the varying irrigation interval may be indicative of a tendency for an interaction with possibly, varying rates of
Potassium Thermodynamics in an Eutric Cambisol

Figure 1a: Q/I biochar/3 day irrigation at seedling

Figure 1b: Q/I compost/3 day irrigation at seedling

Figure 1c: Q/I NPK/3 day irrigation at seedling

Figure 1d: Q/I control/3 day irrigation at seedling

Figure 1e: Q/I biochar/5 day irrigation at seedling

Figure 1f: Q/I compost/5 day irrigation at seedling

Figure 1g: Q/I NPK/5 day irrigation at seedling

Figure 1h: Q/I control/5 day irrigation at seedling

Figure 1i: Q/I biochar/7 day irrigation at seedling

Figure 1j: Q/I compost/7 day irrigation at seedling

Figure 1k: Q/I NPK/7 day irrigation at seedling

Figure 1l: Q/I control/7 day irrigation at seedling
amendments application. This may be a future research possibility.

Table 4: Woodruff free energy classification

<table>
<thead>
<tr>
<th>∆F (cal.mol⁻¹)</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than -3500</td>
<td>Low supplying power of potassium</td>
</tr>
<tr>
<td>-3500 to -2000</td>
<td>Medium/marginal supplying power of potassium</td>
</tr>
<tr>
<td>Greater than -2000</td>
<td>High supplying power of potassium</td>
</tr>
</tbody>
</table>

Source: Woodruff (1955)

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REFERENCES


