# Wet Fixation of Potassium in an Iraqi Soil, Ameriya Silty Clay Loam[1]

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## 1. Introduction

Potassium fixation is observed in many soils, whereby added potassium is rendered un-extractable by ordinary laboratory cation-exchange reagents. Wide interest in the subject was shown in the past on account of its relation to the availability of potassium to plants as well as to the behaviour of the 1:2 expanding lattice-type of the alumino-silicate clay minerals. Due to its suitable size the dehydrated potassium ion is conceived to be the best fitting among cations in the hexagonal voids created by the basal tetrahedral oxygens of adjacent structural units of these minerals (*Page* and *Bavver*, 1940). The polarizability of potassium and other ways were thought to be operative also in both wet and dry potassium fixation (*Schuffelen* and *Marel*, 1955).

Research works concerning potassium fixation and its relation to soil and conditioning factors were discussed and reviewed by *Reitemeier* (1951), *Schuffelen* and *Marel* (1955), *Agarwal* (1960), and *Black* (1968).

Arid and semi-arid soils of Iraq are generally well-supplied with available potassium. Due to increasing cropping intensity in many projects, this investigation, which is the first about the subject, seems feasible.

## 2. Material and methods

*The Soil*

Ameriya silty clay is a calcareous alluvial soil formed under arid climatic conditions in the middle Mesopotamian plain from mixed sediments mostly from Euphrates river. Some of the physical and chemical soil characteristics are shown in table 1.

*Table 1. Some physical and chemical properties of Ameriya silty clay loam[1]*

| | | | |
|---|---|---|---|
| pH of saturated soil paste | 8.09 | Organic matter (%) | 1.83 |
| Specific conductance | | Lime equivalent | 20.00 |
| (mmhos/cm, 25 °C) | 1.40 | Gypsum (%) | 0.77 |
| Soluble ions (me/100 g): | | C. E. C. (me/100 g) | 28.24 |
| $Ca^{++}$ | 0.69 | Moisture at saturation (%) | 55.00 |
| $Mg^{++}$ | 0.53 | Particle size distribution (%): | |
| $K^+$ | 0.039 | sand | 13.0 |
| $Na^+$ | 0.586 | silt | 57.0 |
| $CO_3^{--}$ | 0 | clay | 30.0 |
| $HCO_3^-$ | 0.44 | | |
| $Cl^-$ | 1.37 | | |

[1] Values from the M. sc. thesis by *F. A. A. Latif*, College of Agriculture, Abu Graib/Iraq, 1975.

[1] Contribution from the University of Baghdad (Iraq).
All laboratory work was done at Martin Luther University, Halle (GDR).

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## Methods

Sorbed potassium was determined in soil suspensions at various time intervals in order to determine the time lapse at which approximate equilibrium is established in potassium-treated soil suspensions. In this experiment, 100 g soil samples, on an oven-dry basis, were placed in polyethelyne bags, with 100 ml of potassium chloride solution of increasing concentrations from 50 ppm to 1000 ppm K added. The suspensions were incubated at 27–30 °C, and supernatants were sampled for potassium at 4, 7, 15, 30, and 64 days after mixing. The potassium concentration was determined by EEL flame photometer and sorbed K was then calculated.

The procedure used in the potassium fixation experiment was as follows:

Two grammes of air-dried soil samples were placed in 10 ml centrifuge tubes. Volumes of 1.5 ml, 2.0 ml, and 3.0 ml, each having potassium concentrations of 0 ppm, 500 ppm, 1000 ppm, and 2000 ppm, were added to the soil samples in the centrifuge tubes. Moisture was thus varied as well as potassium concentration. Potassium chloride, potassium nitrate, and potassium sulfate were used as sources of potassium. In the case of potassium sulfate, an additional volume of 1.0 ml was used. The tubes were stoppered and shaken overnight and then placed in a closed desiccator containing some water to provide a humid atmosphere inside. The desiccator was placed for a week in the oven either at 60 °C or at 30 °C. After the lapse of the incubation period, the tubes were centrifuged. The supernatant solutions were filtered, their volumes measured, and the solutions analyzed for potassium. The remaining soil materials were then extracted three times by 6.5 ml of 1 N ammonium acetate, pH 7.0. After each extraction, the soil material was resuspended by properly mixing the reagent and then shaken for ten minutes before recentrifuging. The three extracts were collected together and were made up to 20 ml volume in graduated tubes. Potassium in solutions and extracts was determined by flame photometer, type AAS 1 by Carl Zeiß Jena (GDR).

Exchangeable potassium was calculated from extracted potassium after substracting from the latter the potassium contained in the equilibrium solution remaining inside with the extracted soil material. Fixed potassium ($K_F$) was calculated according to the following formula:

$$K_F = K_A + K_{XC} - K_{XT}.$$

where $K_A$ = added potassium

$K_{XC}$ = sum of soluble ($K_S$) and exchangeable ($K_E$) potassium of the control soil sample

$K_{XT}$ = sum of $K_S$ and $K_E$ of the potassium-treated soil sample.

Added and exchangeable K were expressed on an oven-dry soil basis. Soluble K mentioned or tabulated in this work, however, was always expressed on the solution basis.

To test for the possible effect of microorganisms, one part of potassium nitrate-treated soil samples was sterilized by steam at a pressure of about two atmospheres. Otherwise, all laboratory operations used are the same as previously stated. Soils were found to have normal microflora before sterilization and practically none after it, using the serial dilution method.

## 3. Results and discussion

The sorption of potassium shown in table 2 was initially fast and then changed very little after 7 days of contact. In other soils, important changes in fixed potassium were observed with time (*Anne* and *Marocke*, 1964); such observations, perhaps, are due to differences in the nature of the soils used. The period of 7 days was thus chosen as incubation time.

Table 2. *Sorbed potassium (me/100 g) in relation to time of equilibration at different levels of potassium added in 1 : 1 soil : water suspensions of Ameriya silty clay loam*

| Added potassium (me/100 g) | Days of contact | | | | |
|---|---|---|---|---|---|
| | 4 | 7 | 15 | 30 | 64 |
| 0.128 | 0.041 | 0.046 | – | 0.043 | 0.050 |
| 0.256 | 0.151 | 0.155 | 0.251 | 0.144 | 0.158 |
| 0.512 | 0.362 | 0.354 | 0.358 | 0.352 | 0.348 |
| 0.768 | 0.576 | 0.572 | 0.572 | 0.572 | 0.568 |
| 1.280 | 0.876 | 0.906 | 0.916 | 0.896 | 0.946 |
| 2.560 | 1.878 | 1.898 | 1.908 | 1.898 | 1.888 |

Table 3. *Effect of moisture, temperature, amount of added potassium, and kind of associated anion on the soluble, exchangeable, and fixed potassium in Ameriya silty clay (closed system)[1]*

| Added potassium (ppm) | Soluble potassium (ppm) | | | | | Exchangeable potassium (ppm) | | | | | Fixed potassium (ppm) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | KCl 30°C | KCl 60°C | KNO₃ NS,60°C S | KNO₃ 60°C | K₂SO₄ 60°C | KCl 30°C | KCl 60°C | KNO₃ NS,60°C S | KNO₃ 60°C | K₂SO₄ 60°C | KCl 30°C | KCl 60°C | KNO₃ NS,60°C S | KNO₃ 60°C | K₂SO₄ 60°C |
| *At 150% moisture* | | | | | | | | | | | | | | | |
| 0 | 19.2 | 23.6 | 21.3 | 19.4 | 20.7 | 344.3 | 341.6 | 360.6 | 347.4 | 338.8 | – | – | – | – | – |
| 764 | 95.2 | 108.1 | 99.4 | 103.5 | 95.1 | 889.1 | 820.4 | 893.6 | 907.5 | 870.2 | 105.2 | 158.4 | 105.3 | 70.8 | 168.0 |
| 1527 | 242.6 | 245.4 | 242.2 | 252.6 | 211.7 | 1282.7 | 1230.9 | 1177.1 | 1275.9 | 1419.5 | 253.5 | 305.0 | 361.0 | 229.3 | 206.8 |
| 3055 | 645.4 | 677.1 | 689.5 | 696.3 | 475.7 | 2174.8 | 1970.8 | 1853.6 | 1832.3 | 2242.3 | 285.2 | 445.5 | 504.2 | 498.6 | 516.0 |
| *At 100% moisture* | | | | | | | | | | | | | | | |
| 0 | 24.6 | 29.4 | 24.4 | 28.2 | 22.4 | 345.8 | 345.7 | 360.1 | 369.3 | 369.7 | – | – | – | – | – |
| 509 | 80.7 | 88.2 | 87.6 | 83.6 | 72.0 | 699.5 | 684.4 | 730.5 | 752.4 | 713.4 | 99.2 | 111.5 | 70.7 | 66.4 | 115.7 |
| 1018 | 174.3 | 186.2 | 179.7 | 187.4 | 129.9 | 986.2 | 928.2 | 977.9 | 1019.4 | 1113.0 | 227.9 | 278.7 | 233.4 | 196.9 | 167.2 |
| 2037 | 508.6 | 502.5 | 515.5 | 496.9 | 378.7 | 1698.4 | 1588.2 | 1505.2 | 1458.1 | 1701.9 | 200.4 | 321.4 | 364.5 | 444.8 | 348.5 |
| *At 75% moisture* | | | | | | | | | | | | | | | |
| 0 | 29.4 | 32.2 | 25.2 | 34.9 | 12.8 | 349.4 | 334.5 | 366.8 | 356.8 | 354.6 | – | – | – | – | – |
| 382 | 80.7 | 91.9 | 76.5 | 76.7 | 113.5 | 632.1 | 561.1 | 673.2 | 665.0 | 616.3 | 57.9 | 110.5 | 33.5 | 39.6 | 44.8 |
| 764 | 162.3 | 162.5 | 147.2 | 169.0 | 109.6 | 832.7 | 808.3 | 847.7 | 854.6 | 853.5 | 181.1 | 192.3 | 183.1 | 156.4 | 192.5 |
| 1527 | 380.6 | 396.0 | 471.0 | 206.8 | 296.7 | 1346.8 | 1262.8 | 1278.4 | 1414.4 | 1442.5 | 266.2 | 325.7 | 250.3 | 328.6 | 226.2 |
| *At 50% moisture* | | | | | | | | | | | | | | | |
| 0 | – | – | – | – | 17.2 | – | – | – | – | 355.7 | – | – | – | – | – |
| 255 | – | – | – | – | 46.6 | – | – | – | – | 570.3 | – | – | – | – | 25.7 |
| 509 | – | – | – | – | 68.0 | – | – | – | – | 739.1 | – | – | – | – | 100.2 |
| 1018 | – | – | – | – | 200.6 | – | – | – | – | 1118.5 | – | – | – | – | 163.5 |

[1] All values except those of soluble potassium, which were expressed in ppm on solution basis, are expressed in ppm on the oven-dry soil basis. NS denotes the use of unsterilized soil samples. S denotes the use of sterilized soil samples.

The potassium fixation data obtained in this work are shown in table 3. The net ranges and averages as per cent of $K_A$, which were higher than their respective controls and for all treatments at each temperature used, are shown in table 4 for the various potassium forms.

Table 4. *Net ranges and averages as per cent of $K_A$ for all treatments*

| K form | 30 °C | | 60 °C | |
|---|---|---|---|---|
| | Range | Average | Range | Average |
| $K_S$ | 9.95–23.76 | 16.49 | 9.74–29.19 | 15.90 |
| $K_E$ | 59.92–74.01 | 66.01 | 48.61–84.16 | 64.97 |
| $K_F$ | 9.34–23.70 | 16.41 | 8.77–28.93 | 18.13 |

The average amounts fixed at 60 °C were not very much higher than those at 30 °C, but when the $K_F$ sets of KCl-treated suspensions at 30 °C and 60 °C were compared by the "t" test, differences between values of the two sets were found to be highly significant. The same was found for their corresponding $K_E$, but their $K_S$ values had significant differences only at the 5 % probability level. As reflected by these averages, the increase in temperature resulted in an increase in $K_F$ accompanied by a decrease in $K_E$ and to a lesser degree in

Table 5. *Properties of lines and curves of relations for various forms of potassium*

| Treatment and variables | Type of equation[1] | a | b | c | r |
|---|---|---|---|---|---|
| *KCl, 30 °C* | | | | | |
| $y = K_F$, $x = K_S$ | 1 | 0.358 | 101.19 | – | 0.8003 |
| | 2 | 18 415 | 0.0056 | – 18 777 | 0.9346 |
| $x = K_E$ | 1 | 0.140 | 29.17 | – | 0.8084 |
| | 2 | 19 236 | 0.0092 | – 20 362 | 0.8838 |
| $x = K_A$ | 1 | 0.082 | 86.87 | – | 0.8107 |
| | 2 | 17 592 | 0.0066 | – 18 221 | 0.9287 |
| $y = K_E$, $x = K_S$ | 1 | 2.516 | 519.85 | – | 0.9778 |
| *KCl, 60 °C* | | | | | |
| $y = K_F$, $x = K_S$ | 1 | 0.500 | 113.37 | – | 0.9155 |
| | 2 | 33 648 | 0.0042 | – 34 166 | 0.9592 |
| $x = K_E$ | 1 | 0.233 | – 4.83 | – | 0.9434 |
| | 2 | 11 874 | 0.0196 | – 13 346 | 0.9579 |
| $x = K_A$ | 1 | 0.125 | 88.22 | – | 0.9458 |
| | 2 | 167 | 0.2164 | – 510 | 0.9730 |
| $y = K_E$, $x = K_S$ | 2 | 61.316 | 0.529 | 55.756 | 0.99073 |
| *KNO₃, 60 °C* | | | | | |
| $y = K_F$, $x = K_S$ | 1 | 0.679 | 41.37 | – | 0.9226 |
| $x = K_E$ | 1 | 0.394 | – 210.56 | – | 0.9492 |
| $x = K_A$ | 1 | 0.179 | – 1.53 | – | 0.9537 |
| *K₂SO₄, 60 °C* | | | | | |
| $y = K_F$, $x = K_S$ | 1 | 0.909 | 22.95 | – | 0.9248 |
| $x = K_E$ | 1 | 0.254 | – 93.33 | – | 0.9556 |
| $x = K_A$ | 1 | 0.160 | 11.20 | – | 0.9728 |
| *All salts at 60 °C* | | | | | |
| $y = K_F$, $x = K_S$ | 1 | 0.658 | 59.62 | – | 0.9044 |
| $x = K_E$ | 1 | 0.296 | – 107.66 | – | 0.9084 |
| $x = K_A$ | 1 | 0.162 | 21.78 | – | 0.9471 |

[1] 1: $y = ax + b$
2: $y = ax^b + c$

All calculations were done without the $K_S$, $K_E$, and $K_F$ values of the control samples ($K_A = 0$).

$K_S$. Such a redistribution indicates that the main direct source of $K_F$ was $K_E$. The probable main movement of $K_A$ to the fixing sites could be visualized to take place in two steps: The first from $K_S$ to $K_E$, and the second from $K_E$ to $K_F$. It should be noted, however, that such a scheme for potassium fixation does not contradict the co-existance of other ways of potassium fixation such as the precipitation of potassium as insoluble compounds (*Schuffelen* and *Marel*, 1955). The above scheme simply appears to be the main one operative in the soil system studied. Table 5 shows the relation between $K_F$ and $K_A$, $K_S$, $K_E$ for the KCl-treated suspensions at 30 and 60 °C. Although these relations were found to fit straight-line equations ($y = ax + b$) with highly significant correlation coefficients, they were, nevertheless, found to fit the parabolic equation $y = ax^b + c$, where a, b and c are constants, with higher positive correlation coefficients; this signifies a better fitness for the parabolic function. A study of these relations shows that at both temperatures, 30 and 60 °C, $K_F$ increased with decreasing rates as each of the variables $K_A$, $K_S$ and $K_E$ increased. At any level of each of the latter variables, $K_F$ at 60 °C was higher than that at 30 °C; the difference being greater at higher levels of the variables. Furthermore, at 60 °C, the stated $K_F$ relations fitted the straight-line equation better than corresponding ones at 30 °C, as can be judged from the calculated correlation coefficients (table 5). This observation signifies that the $K_F$ relations at 60 °C, especially $K_F$ vs. $K_A$ and $K_F$ vs. $K_E$, are closer to straight lines than the corresponding ones at 30 °C. Moreover, highly significant correlation coefficients were obtained for the straight-line equations fitting the $K_F$ data at 60 °C in relation to $K_A$, $K_S$, and $K_E$, when the latter three variables were pooled together irrespective of kind of salt or the moisture level of the soil suspensions (fig. 1).
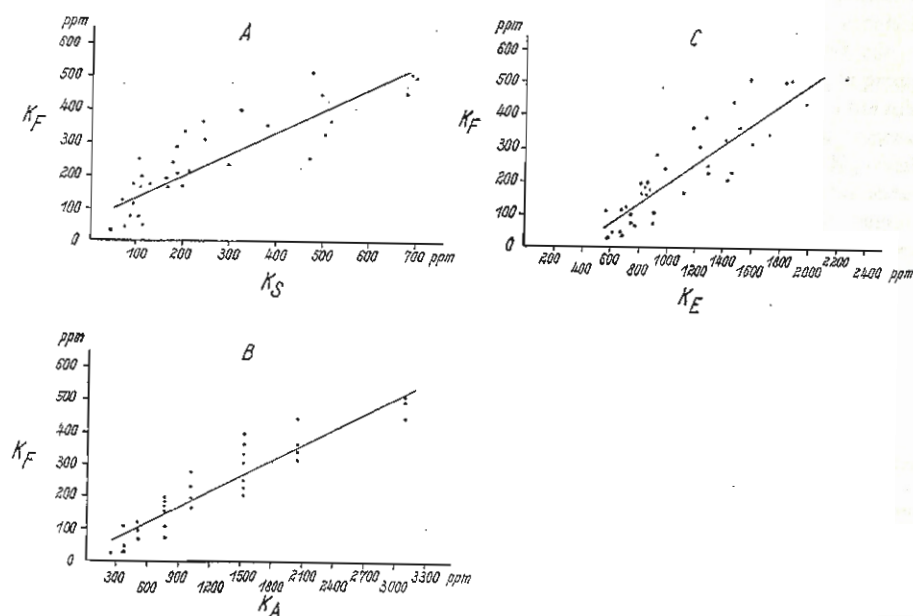


Fig. 1. Fixed potassium, $K_F$, at 60 °C irrespective of moisture level and kind of added salt in relation to corresponding:

A. soluble potassium, $K_S$     B. added potassium, $K_A$     C. exchangeable potassium, $K_E$

Differences between the $K_F$ versus $K_S$, $K_E$ and $K_A$ relations at 30 °C and those at 60 °C can be explained mainly on the basis of temperature influences on potassium mobility and on the physical properties of the soil. The increase in temperature, apparently, produced a physical condition conducive to potassium movement and diffusion inside and between soil aggregates and particles. Dissolution and dislocation of lime, gypsum, organic compounds, and other aggregate-binding materials, that could have been caused by aqueous solution and evolved gases at 60 °C, may have resulted in rather open, swollen and perhaps degraded soil aggregates. Such an effect of a temperature increase on the physical condition of soil material can expose new solid surfaces with K-unsaturated fixing sites. With increased rates of reactions and an increased potassium diffusion at 60 °C, the transfer of potassium from the solution phase to the newly fixing sites would be facilitated conceivably. The higher levels of $K_A$ used in this fixation study were apparently sufficient at the prevalent experimental conditions to nearly saturate at 30 °C what were available from these K-fixing sites, and hence the tendency of $K_F$ to level off at higher values of the variables $K_S$, $K_A$, and $K_E$. At 60 °C, on the other hand, there was a greater decrease of potassium as well as better conditions for its transfer so that no such tendency was feasible at the higher levels of these variables. Instead, these relations at 60 °C approach straight lines (fig. 1).

The effect of moisture on the potassium fixation (table 3) appears to be very limited in the moisture range used. This result is generally in line with the observations of *Ahmad* and *Davis* (1970), who found practically no influence of moisture in the range of 0.5 to 1.6 of the field capacity on the level of fixed potassium.

The "t" test comparisons between each of the $K_F$, $K_S$, and $K_E$ sets of values of the sterilized potassium nitrate-treated suspensions and those of the unsterilized ones showed no significant differences.

As regards the effect of different anions contained in the potassium salts added at 60 °C on the potassium forms, it may be said that it was generally limited to the lower levels of $K_A$. Fig. 2 shows that the $K_S$ curve for the KCl-treated suspensions was almost identical with
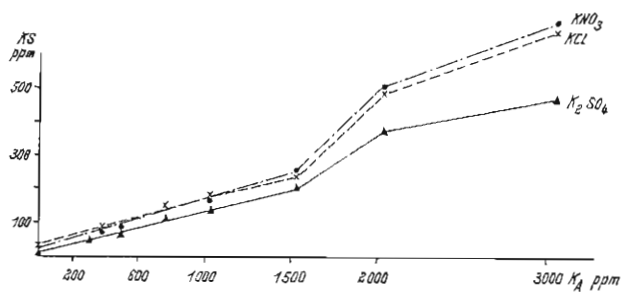
Fig. 2. Soluble potassium, $K_S$, in relation to added potassium, $K_A$, derived from different salts at 60 °C

that of the KNO₃-treated ones, throughout the whole range of $K_A$. The $K_S$ values of K₂SO₄-treated suspensions, however, were somewhat lower than comparable values of KCl and KNO₃-treated suspensions, especially at the three highest levels of $K_A$. This behaviour was reflected but to a lesser degree in the $K_E$ values, which were generally higher in K₂SO₄-treated suspensions than those of KNO₃ and KCl ones (fig. 3). In Indian soils, however, K₂SO₄-treated suspensions were found to have a lower $K_E$ than those of corresponding KNO₃- and KCl-treated suspensions (*Misra* and *Shanker*, 1971). "t" test comparisons of
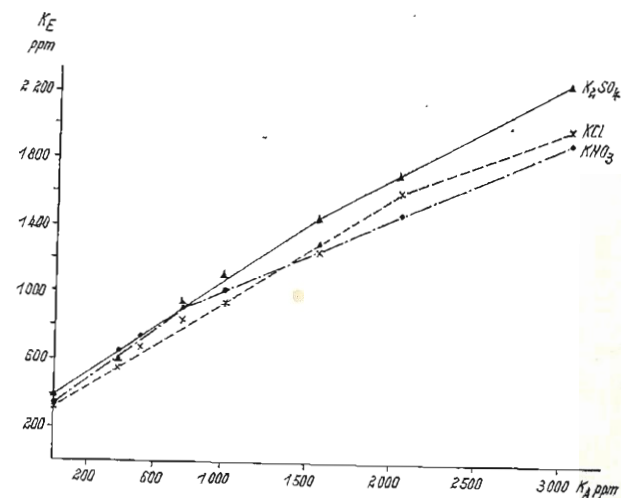
Fig. 3. Exchangeable potassium, $K_E$, in relation to added potassium, $K_A$, derived from different salts at 60 °C

sets of the $K_F$ values of the three salts used showed, however, that the anion effect on the $K_F$ values was non-significant. This result is different from that obtained in similar work (*Ahmad* and *Davis*, 1970), where KNO₃- and K₂SO₄-treated suspensions had comparatively less $K_F$ than KCl-treated ones. It is very likely that the prevalence of ionized, adsorbed, and combined calcium as carbonates and gypsum in Ameriya soil promoted the precipitation of calcium sulfate compounds, especially at the highest three levels of potassium sulfate, added, thus resulting in higher $K_E$ and lower $K_S$ when compared with the corresponding forms derived from added KNO₃ and KCl solutions. Differences in $K_S$ and $K_E$ obtained in this work in the K₂SO₄-treated suspensions were apparently too small to be reflected in the $K_F$ values. The formation of the ion KSO₄⁻ appears to be too small in magnitude (*Adams*, 1971) to account for the observed potassium distribution in the K₂SO₄-treated soil system.

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# Summary

*Taba Naji*, *W. Römer*, and *G. Schilling*: Wet fixation of potassium in an Iraqi soil, Ameriya silty clay loam

The wet fixation capacity of K was studied under varying conditions in an alkaline, calcareous, and alluvial Iraqi soil. The variations concerned the soil-water proportion, K concentration, type of K salt added, and temperature, with the time for equilibrium calibration remaining constant at seven days. K fixation increases with increased K addition, i. e. with an increased content of water soluble and exchangeable potassium, but also with an increase in temperature from 30 to 60 °C. Increasing the temperature changes the relation between the level of the K addition and its fixation. Factors like the relation between soil and solution, type of K salt, and microbial activity do not exert any remarkable influence on the fixation.

*Taba Naji*, *W. Römer* und *G. Schilling*: Naßfixierung von Kalium eines irakischen Alluvialbodens (Ameriya, lehmiger Tonboden)

Ein alkalischer karbonathaltiger Alluvialboden aus dem Irak wurde unter verschiedenen Bedingungen auf sein Vermögen zur nassen K-Fixierung untersucht. Variiert wurden Verhältnis Boden zu Wasser, K-Konzentration, Art des zugegebenen K-Salzes und Temperatur bei gleichbleibender Zeit für die Gleichgewichtseinstellung von sieben Tagen. Die K-Fixierung steigt mit der K-Zugabe, d. h. mit der Erhöhung des Gehaltes an wasserlöslichem und austauschbarem Kalium, aber auch mit der Erhöhung der Temperatur von 30 auf 60 °C. Die Temperaturerhöhung verändert die Beziehung zwischen Höhe der K-Zugabe und Fixierung. Die Faktoren Verhältnis Boden zu Lösung, Art des K-Salzes und mikrobiologische Aktivität sind praktisch ohne Einfluß auf die Fixierung.

*Taba Naji*, *W. Römer* и *G. Schilling*: Мокрав фиксация калия в одной иракскои аллювиальной почйе (Америи, глина)

Щелочная, содержащая карбонат аллювиальная почва из Ирака исследовалась в различных условиях опыта на способность к мокрой фиксации калия. Варьировалось соотношение почвы и воды, концентрация калия, вид калийной соли и температура при постоянности времени достижения состояния равновесия 7 дней. Фиксация возрастает с дозой калия, т. е. с увеличением содержания водорастворимого и обменного калия, а также с возрастанием температуры с 30 до 60 °С. Повышение температуры изменяет соотношение между величиной внесённого калия и его фиксацией. Факторы как соотношение почвы и раствора, вид калийной соли и микробиологическая активность практически не влияют на фиксацию калия.

*Taba Naji*, *W. Römer* et *G. Schilling*: Fixation par voie humide de potassium d'un sol alluvial irakien (Ameriya, sol argileux glaiseux)

Un sol alluvial alcalin carbonaté de l'Iraq a été examiné, dans des conditions différentes, en vue de sa capacité de fixation par voie humide de potassium. Ont été variés le rapport sol eau, la concentration de K, le genre du sel de potasse additionné et la température à temps constant pour la mise en équilibre de sept jours. La fixation de potassium augmente avec l'addition de K, c'est-à-dire avec l'augmentation de la teneur en potassium soluble dans l'eau et échangeable, mais aussi avec l'augmentation de la température de 30 à 60 °C. L'augmentation de la température change le rapport entre la quantité de l'addition de K et la fixation. Les facteurs rapport sol solution, genre du sel de potasse et activité microbiologique restent pratiquement sans influence sur la fixation.

*Taba Naji*, *W. Römer* y *G. Schilling*: La fijación en húmedo de potasio de un suelo aluvial iraquí (Ameriya, suelo arcilloso limoso)

Un suelo aluvial alcalino conteniendo carbonato del Irak se analizó bajo condiciones diferentes a su capacidad de fijación de K en húmedo. Se varió la relación suelo a agua, la concentración de K, el tipo de sal potásica y la temperatura mantiendo invariable el tiempo para la regulación del equilibrio de siete dias. La fijación de K aumenta con la aplicación de K, es decir, con el aumento del contenido en potasio soluble en agua y inter-cambiable, pero también con el aumento de la temperatura de 30 a 60 °C. El aumento de la temperatura modifica la relación entre la importancia de la aplicación de K y la fijación. Los factores relación del suelo a la solución, tipo de la sal potásica y actividad microbiológica prácticamente no tienen influencia sobre la fijación.

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