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In the name of Allah

POTASSIUM IN LEBANESE SOILS AS REFLECTED BY ELECTRO-ULTRAFILTRATION, CHEMICAL EXTRACTION, AND CROPPING[1]

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ABSTRACT

Short-term plant growth stdudies **have indicated** that Lebanese **soils are** adequate in available K, **but there** are no estimates of their long-term supplying power. Therefore, this aspect was studied by electro-ultrafiltration (EUF), extraction with 1N HNO_3 and IN NH_4OAc, and by successively taking one corn (*Zea mays* L.) and six Italian ryegrass (*Lolium multiflorum* L.) crops in the greenhouse. There was no significant response to K fertilization at any harvest. Total uptake in the six untreated soils was significantly related to both exchangeable and HNO_3- extractable K. Amounts of K extracted after 10 and 35 min. by EUF were related to water-soluble and exchangeable K, respectively. However, EUF

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بنام خدا

اندازه‌گیری پتاسیم درخاکهای لبنان بوسیله الکترو ولترا فیلتراسیون و عصاره‌شیمیائی ومقدار محصول

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خلاصه

مطالعات کوتاه مدت برروی رشدگیاه نشان داده است که پتاسیم مورداستفاده بمقدارکافی درخاکهای لبنان موجود میباشدولی هیچگونه تخمینی ازمیزان توانائی خاکها وعرصه پتاسیم دردراز مدت دردست نیست . بنابراین،دریک آزمایش گلخانه ای،این جنبه توسط الکترو ولترا فیلتراسیون، عصاره‌گیری با محلولهای یک نرمال اسیدنیتریک و استات آمونیم وکشت متوالی ذرت وبرداشت شش چین چمن موردمطالعه قرار گرفت . افزایش کودپتاسیم منجربه بروز واکنش معنی داردربرداشت محصول نگردید .درشش خاک که به آنها پتاسیم اضافه نشده بود ،جذب کل پتاسیم با پتاسیم قابل تبادل وعصاره‌گیری شده بوسیله اسیدنیتریک همبستگی معنی داری رانشان داد .مقدارپتاسیم عصاره‌گیری شده پس از ۱۰ و۳۵ دقیقه بوسیله الکترو ولترافیلتراسیون بترتیب باپتاسیم محلول درآب وقابل تبادل ارتباط داشت اما پارامترهای الکترو ولترافیلتراسیون با میزان

parameters were poorly related to both K uptake and plant K concentrations. Since exchangeable K was a good estimate of both short- and long-term available K in these soils with high levels of exchangeable K, more sophisticated procedures such as EUF may not always be necessary. The study has implications for soils of arid and semi-arid regions which tend to be relatively unweathered and comparatively rich in available K.

جذب وغلظت پتاسیم درگیاه رابطه ضعیفی رانشان دادند. ازآنجاکه مقدار پتاسیم قابل تبادل درچنین خاکهائی معیارخوبی جهت تخمین میزان پتاسیم قابل استفاده درکوتاه مدت ودرازمدت بود، استفاده ازروشهای پیچیده ترمانند الکترواولترافیلتراسیون ممکن است همیشه لزومی نداشته باشد. نتایج این مطالعه برای خاکهای مناطق خشک ونیمه خشک که درآنها هوادیدگی نسبتاً صورت نگرفته وبطورنسبی ازنظرپتاسیم قابل تبادل غنی هستندقابل تعمیم میباشد.

INTRODUCTION

Soils of the Middle East, and arid regions in general, tend to be well supplied with plant available K, except for those that are sandy and intensively cropped under irrigation. Short-term cropping experiments in Lebanon have shown virtually no response to added K (1, 3). Though some soils may not respond to K application, the supplying power may be quite limited as indicated by Martini and Suarez (6) for some tropical soils. Assessment of the capacity factor for soil K is particularly crucial with high K-requiring crops. The K-supplying power has been measured by successive cropping of Peruvian (11) and Costa Rican (6) soils. Chemical procedures such as extraction with 1N HNO_3 (nitric acid) and 0.3N NaTPB (sodium tetraphenylborate) have been used to replace the more time-consuming growth experiments. As exchangeable K is, theoretically, in equilibrium with slowly-available K, extraction by NH_4OAc (ammonium acetate) should also reflect the supplying power.

Non-chemical methods such as electrodialysis have shown good correlation with long-term crop K uptake. Electro-ultrafiltration (EUF), a modified electrodialysis technique was used by Nemeth (7) as a new approach to soil testing. This procedure is designed to characterize the behavior of cations and anions in soils. EUF parameters are postulated to reliably reflect intensity, exchangeable K, and the buffering and K fixation capacities. Desorption curves obtained by EUF and soil solution K concentration were shown to behave similarly after fertilization (8).

The rapidly developing interest in EUF was reflected in the first conference on its use in agricultural production (Budapest, May 1980); the proceedings (10) highlight not only the potential of EUF for characterizing soil K but also for other nutrient elements such as N, P, and B.

Though the EUF procedure appears to have considerable potential for soil research and testing, its application to date has been limited, especially in arid-region soils. Therefore, the objectives of this study were to evaluate the K-supplying power of six representative Lebanese soils by EUF, extraction by 1N NH_4OAc and 1N HNO_3, and by successive cropping.

MATERIALS AND METHODS

Soil samples were collected from different areas of Lebanon. Two samples were from uncultivated areas in the Cedar region of Mount Lebanon, one uncultivated soil from the eastern slope of these mountains (Der-el-Ahmar), and three samples from important cultivated soils in the central Beqa'a valley. The samples were taken to a depth of 20 cm, air-dried and passed through a 0.5-cm screen for greenhouse and laboratory studies. Selected soil properties are presented in Table 1.

For the greenhouse study, 1.5 kg soil lots were potted and mixed with K_2SO_4 solution to give 100, 500, and 750 mg K per pot, with four replications. Six seeds of corn (*Zea mays* L. var. 'Funk 266 Double Cross') and 1 g of Italian ryegrass (*Lolium multiflorum* L.) seeds were sown in each pot. Upon emergence, corn was thinned to five seedlings per pot. Nitrogen was added in solution at 450 mg/pot at planting, and after each harvest. Phosphorus

Table 1. Properties of experimental soils before K additions and cropping.

Soil	pH	Organic matter (%)	$CaCO_3$ (%)	Clay (%)	CEC (meq/100g)	Forms of Soil K: Exchangeable (meq/100g)	Forms of Soil K: 1 N HNO_3-extractable (meq/100g)	Forms of Soil K: Water soluble (ppm)	Forms of Soil K: Total (%)
Kfardan	7.5	1.7	1.2	57.0	37	1.63	4.56	3.0	1.34
Sifri	7.6	1.4	2.0	47.5	34	1.76	6.14	3.0	1.85
Kabelias	7.8	2.0	18.0	18.0	9	0.37	1.40	3.0	0.52
Der-el-Ahmar	7.5	1.6	1.5	65.0	32	1.11	4.42	1.1	1.56
Cedar A	7.6	4.4	0.9	51.0	42	1.19	4.53	1.7	1.60
Cedar B	7.9	2.9	42.0	20.5	24	0.94	2.89	1.8	1.15

at 420 mg and Mg at 90 mg/pot were added before planting. These nutrients were added in solution to the soil after each harvest to ensure that no element other than K would limit growth. After 6 weeks, the corn was harvested. Six harvests of ryegrass were subsequently taken over the next 7 months. After oven-drying at 75°C, the plant material was digested with HNO_3-$HClO_4$ and K was determined by flame photometry.

Background analyses were performed by conventional methods; pH with pH meter on 1:2.5 soil-water extract, organic carbon by that of Walkley-Black, and $CaCO_3$ equivalent by CO_2 measurement with a Bernard calcimeter using 10% HCl. Cation exchange capacity was determined using saturation with 1N NH_4Cl (pH 8.5) and displacement with a 25% KCl solution. Clay minerals were determined according to Jackson (4). The soils, in general, contained roughly equal amounts of illite and kaolinite with smaller amounts of montmorillonite and vermiculite. The exceptions were traces of illite for the Kabelias soil and somewhat higher amounts of illite and kaolinite for the Der-el-Ahmar soil.

Water-soluble K was determined in a saturation extract. Exchangeable K was calculated by subtracting water-soluble K from that extracted by 1N NH_4OAc. The K-suuplying power was estimated by the amounts of K removed by extraction with 1N HNO_3. Total K was determined according to the method of Jackson (5). Potassium was extracted by EUF according to Nemeth (7) as follows: A 5 g air-dry soil sample was extracted with deionized water. The amount of water in the soil suspension was kept constant at about 50 ml. The extraction was carried out at room temperature with water at 15°C circulating through the cooling system. During the 35 min extraction period, voltage was varied as follows: 50 V the first 5 min , 200 V the next 25 min , and 400 V during the last 5 min. Potassium in each 5 min extract was determined by atomic absorption spectrophotometry.

RESULTS AND DISCUSSION

Despite variation in K forms, there was no significant response to K at any rate of application as reflected by corn dry matter for the first growth period (Fig. 1). Yields for each harvest varied depending on growth period and environmental conditions, but even after six ryegrass croppings, there was no obvious decrease in yield. Total dry matter yields of corn and ryegrass were not significantly increased by K application on any soil.

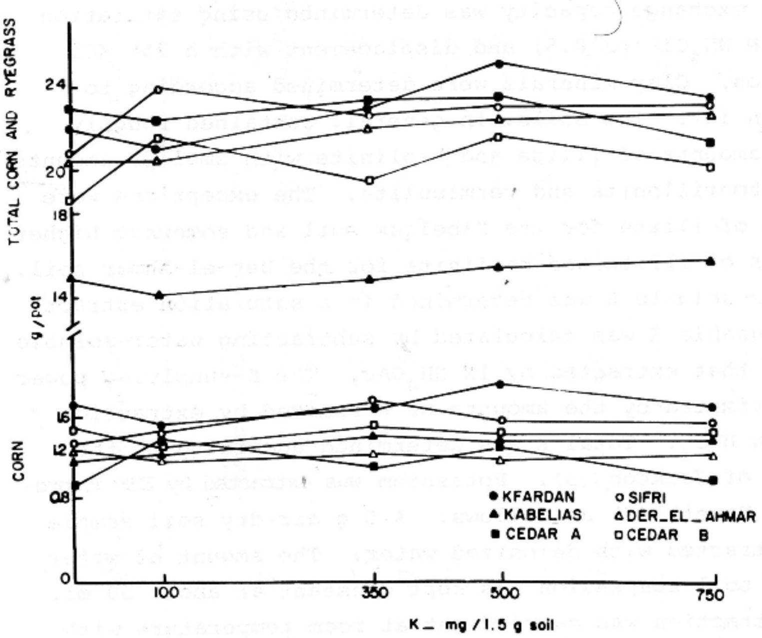

Fig. 1. Crop dry matter yields in relation to K fertilization of six soils.

The absence of any yield increase suggests that not only was K initially well supplied, but that the soils were able to supply it at adequate rates for subsequent extraction by plants. Since K was sufficient and all other essential nutrients applied, the comparatively lower total dry matter from the Kabelias soil must be explained by factors other than nutrition. The most likely explanation is that the lighter texture might be a limiting factor with respect to soil-water relationships and nutrient diffusion. Though the Kabelias soil was comparatively lower in all forms of K and illite, a K-supplying mineral, exchangeable K values were still higher than what is generally accepted as critical, below which a deficiency is likely. Based on the criteria of Doll and Lucas (2); i.e. 0.22 meq/100g for loamy sands to 0.32 meq/100g for clays, a growth response would be unlikely on any of the six soils.

In the absence of a growth response, the K-supplying characteristics of the soil may be validly assessed by considering plant K concentrations. Plant K increased in proportion to the amounts added only in the first corn crop. Moreover, the change in percent K with increasing application rates varied with the soil; i.e. Cedar B, 3.5-7.1, Kabelias, 3.8-6.9, Cedar A, 4.7-7.0, Der-el-Ahmar, 4.9-7.1, Sifri, 5.6-7.2, and Kfardan, 6.3-7.3. For all subsequent ryegrass harvests there was no effect of added K. Plant K concentrations for the corn and the six subsequent ryegrass croppings of the unfertilized soils are presented in Fig. 2. Potassium concentrations in the initial corn crop were relatively high and varied with the soil. While the values were less with ryegrass, there were no obvious or consistent differences among soils except for the Kabelias soil. Furthermore, there were no apparent differences with increasing ryegrass harvest. Thus it would appear that, although K was taken up initially in luxury amounts, sufficient K was apparently released throughout the growing

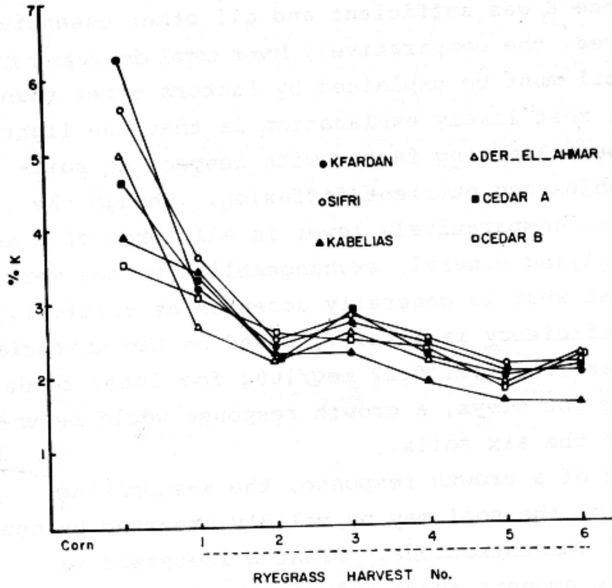

Fig. 2. Potassium concentrations in corn and Italian ryegrass grown on unfertilized soils.

period at physiologically adequate levels according to criteria for K tissue concentrations.

Though soil K behavior is most reliably reflected in crop growth data, it is pertinent, in this case, to consider other estimates of both the short- and long-term K availability and the relationships between them. In the EUF procedure, Nemeth (7) suggested that the amount of K desorbed after 10 min represents the K concentration in the soil solution or the intensity factor, while the sum of K released after 35 min reflects the quantity factor or exchangeable K. The amounts of K released from 30 to

35 min at 400 V reflect the soil capacity to release K from less available sources; the steeper this part of the desorption curve the higher the amounts of K released over the growing season.

Extraction curves by EUF for four of the six soils showed a similar pattern, with amounts extracted after 30-35 min being greater than extracted after 5-10 min (Fig. 3). In other words, these soils not only had an initial high level of exchangeable K but also a high buffering capacity as indicated by the extraction curves. Though the EUF data suggest differences between the Kabelias and Der-el-Ahmer

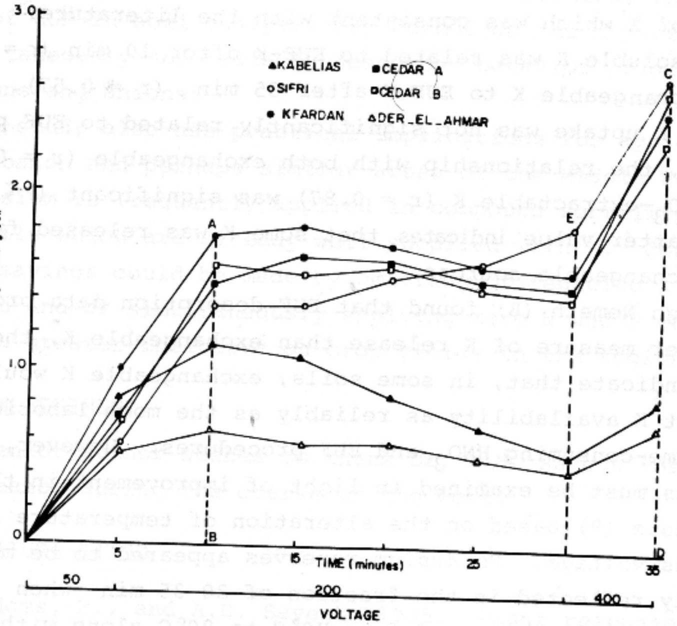

Fig. 3. Desorption of K with electro-ultrafiltration (EUF).

soils with respect to K, such differences were not greatly reflected in either yield or plant K concentrations.

Such a discrepancy, at least, questions the reliability of EUF as a procedure for adequately characterizing soil K behavior. The poor relationships observed here may be attributed to the high initial levels of exchangeable K, since the good agreement found by Nemeth (8) was obtained for soils with a lower range of exchangeable K; i.e. 0.23-0.46 meq/100g soil. Furthermore, for water-logged soils with even lower levels of initial exchangeable K, Wanasuria *et al.* (12) showed that EUF-K was more closely related to rice (*Oryza sativa* L.) yield than exchangeable K. However, in this study, the EUF data showed a relationship to soil forms of K which was consistent with the literature. Water-soluble K was related to EUF-K after 10 min ($r = 0.59$) and exchangeable K to EUF-K after 35 min ($r = 0.57$). Though K uptake was not significantly related to EUF parameters, the relationship with both exchangeable ($r = 0.86$) and HNO_3-extractable K ($r = 0.87$) was significant ($P \leq 0.05$). This latter value indicates that some K was released from non-exchangeable sources.

Though Nemeth (8) found that EUF desorption data provided a better measure of K release than exchangeable K, these data indicate that, in some soils, exchangeable K would predict K availability as reliably as the more laborious and time-consuming HNO_3 and EUF procedures. However, these results must be examined in light of improvement in the EUF procedure (9) based on the alteration of temperature as well as voltage. Potassium reserves appeared to be more clearly reflected in the fraction of 30-35 min when temperature is increased from 20°C to 80°C along with an increase in voltage from 200 to 400.

In conclusion, this study indicated that Lebanese soils have a high capacity to supply K to plants. This reflected their poorly weathered status, comparatively high CEC, and content of illite. While EUF parameters may reflect intensity, rate, and quantity factors of soil K, some discrepancies did exist between EUF and biological evaluation of soil K. However, more definitive conclusions regarding EUF-K should be based on a wide range of soils with considerable variation in clay minerals and in the degree of K saturation of the exchange complex. Nevertheless, in view of the fact that intensity and quantity of soil K can be readily and reliably estimated by chemical procedures, the refinements achieved by EUF may not always be warranted, especially as a routine analysis. The ammonium acetate procedure for exchangeable K, with measurement of K by flame photometry, is likely to remain in vogue, particularly in developing countries. Elsewhere, extended use of EUF in soil analysis may depend on its capacity to simultaneously and reliably describe behavior of other cations and anions.

The study also has practical implications for agriculture in Lebanon and perhaps similar areas of the Middle East. Potassium is frequently applied in compound fertilizers to soils which are already well supplied with K. Considerable savings could be made by omitting or reducing K application and/or simultaneously applying more N and P which have a greater influence on crop yields in the region.

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LITERATURE CITED

1. Adams, F., and A.H. Sayegh. 1955. Plant response to nitrogen, phophorus and potassium in soils of Lebanon as indicated by greenhouse pot experiments. Pub. 1. Fac. Agric. Sci., Amer. Univ. Beirut.

2. Doll, E.C., and R.E. Lucas. 1973. Testing soils for

potassium, calcium, and magnesium. p. 133-151. *In* L. M. Walsh and J.D. Beaton (eds.). Soil testing and plant analysis. Soil Sci. Soc. Amer., Madison, WI.

3. Fuehring, H.D., and M.D. Abi-Antoun. 1968. Tests for available phosphorus, potassium and magnesium on ten soils of the Middle East. Pub. 33, Fac. Agric. Sci., Amer. Univ. Beirut.
4. Jackson, M.L. 1956. Soil chemical analysis - Advanced course. Published by the author. Madison, WI.
5. Jackson, M.L. 1964. Soil chemical analysis. Prentice-Hall Inc., Englewood Cliffs, New Jersey.
6. Martini , J.A., and A. Suarez. 1977. Potassium supplying and fixing capacity of some Costa Rica latosols and andosols determined by sucessive cropping extractions and incubations. Soil Sci. 123: 37-47.
7. Nemeth, K. 1972. The determination of desorption and solubility rates of nutrients in the soil by means of electro-ultrafiltration (EUF). Proc. 9th Colloquium, Int. Potash Inst.
8. Nemeth, K. 1975. The effect of K fertilization and K removal by ryegrass in pot experiments on the K concentration of the soil solution of various soils. Plant Soil 42: 97-107.
9. Nemeth, K. 1979. The availability of nutrients in the soil as determined by electro-ultrafiltration (EUF). Adv. Agron. 31: 155-187.
10. Nemeth, K. 1982. Application of elecro-ultrafiltration (EUF) in agricultural production. Plant Soil 64: 1-138.
11. Oelsligle, D.D., E.C. Doll, and C. Valverde. 1975. Potassium release characteristics of selected Peruvian soils. Soil Sci. Amer. Proc. 39: 891-896.
12. Wanasuria, S., S.K. de Datta, and K. Mengel. 1981. Rice yield in relation to electro-ultrafiltration extractable soil potassium. Plant Soil 59: 23-31.