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Annals of Biological Research, 2013, 4 (7):165-170
(http://scholarsresearchlibrary.com/archive.html)

ISSN 0976-1233
CODEN (USA): ABRNBW

Comparison of ammonium acetate at different concentrations and some extractants for determination of plant-available potassium in different soils of Chahar Mahal and Bakhtiari province in Iran

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ABSTRACT

The extractions of soil potassium (K) bychemical methods werecompared as predictors of plant-available K forpot-grownPinto beans (Phaseolus vulgaris) on Charmahal Va Bakhtyari-Iran soils. The treatments included two K levels [0 and 200 mg K kg^{-1} as potassium sulfate (K_2SO_4)] and 15 soils in a factorial experiment in a randomized block design with three replications.The result indicated that K application increased yield, K concentration and K uptake by bean. Relationships between methods werediscussed. The 8 extracting solutions used in this study wereclassified into3 groups on the basis of K extracted.The correlationstudies showed that 0.002 M $SrCl_2$, 0.02 M $SrCl_2$+0.05 M citric acid, and 1 M NaCl, could be used as available K extractants. Potassium critical levels by extractants were also determined by Cate-Nelson method. Potassium critical levels for 90% of relative yield were 38, 80, and 136 mg kg^{-1} for 0.002 M $SrCl_2$, 0.02 M $SrCl_2$ +0.05 M citric acid, and 1 M NaCl, respectively.

Keywords: Available potassium, extractants, bean, critical level.

INTRODUCTION

Potassium (K) is one of the major nutrients elements to the plants.Soil potassium exists in solution, exchangeable, and non-exchangeable forms that are in dynamic equilibrium with each other. Plant can absorb water soluble and exchangeable potassium from soil, which together called as available potassium[6]. Solution and exchangeable K are replenished by nonexchangeable Kwhen they are depleted by plant removal or leaching.Soil testing methods using extracting solutions try to measure this replenishmentrate. The comparison of different soil tests for K extraction is often done among soil scientists[16, 18]. The first purpose of each extractant is the determination of availablenutrients for plants. When utilizing an extractant, two parametersare very important: (i) evaluating the nutrient labile form and (ii) extractingmethods that are fast and economic [5].The neutral 1 M ammonium acetate (NH_4OAc) method, which extracts both solution and exchangeable K^+, is the most common soil test method used to develop Kfertilizer recommendations [8].Aramrak et al. (2007)used Mehlich 3, ABDTPA, and 1 M NH_4OAc in extracting available K for corn in Thai soils[2]. They found that AB-DTPA, Mehlich 3, and 1 M NH_4OAc extractants were good indices for K availability. Tafaroji et al. (2005) recommended Morgan and Ammonium Acetate (1:20) solutions for determination of the available K for cornin some soils of Guilan province[23].The availability of K for plant depends on soil, plant, and climate factors. Therefore, it is necessary to assess the ability of K extractants to predict plant-available K in a wide range of soils and plants. The objectives of this study were: i) to compare K extractions by chemical methods as predictors of bean-available K on a wide range of soils, ii) to assess the ability of Ammonium Acetateat different concentrations to predict exchangeable K, and iii) to determine K critical levels by different extracting solutions.

MATERIALS AND METHODS

Fifteen surface-soil samples (0–15 cm) were obtained from fields in different locations of the province of CharmahalVaBakhtyari, Iran. The soil sampleswere analyzed for some properties like pH in a 2:1 soil–water ratio [24], organic carbon (C) [15], cation exchange capacity (CEC) [22], electrical conductivity in a 2:1 soil–water ratio [17], equivalent calcium carbonate [12], and clay content [7]. Some selected physical and chemical properties of the soils are given in Table 1.The determination of K availability was estimated by the methods are shown in Table 2. Potassium, in all extracts, was determined using atomic emission spectroscopy.

Table 1 Selected chemical and physical characteristics of soils studied

Soil no.	pH^a	EC^a ($ds\ m^{-1}$)	CEC ($Cmolc\ kg^{-1}$)	Eq. CaCO3 (%)	O.C (%)	Clay (%)	Silt (%)	Sand (%)
1	8.07	0.13	20.1	29	0.58	35	32	33
2	7.85	0.17	16.0	34	0.56	33	36	31
3	7.74	0.19	15.5	23	0.8	47	30	23
4	8.05	0.11	15.8	17	0.8	41	42	17
5	8.02	0.17	19.3	26	1.3	39	46	15
6	8.10	0.16	16.7	40	0.66	53	32	15
7	7.92	0.19	24.3	31	1.53	45	24	31
8	7.92	0.12	18.0	25	0.64	35	34	31
9	7.92	0.11	19.2	17	0.65	35	52	13
10	7.92	0.14	20.1	18	0.74	31	32	37
11	7.88	0.17	19.3	6	0.67	33	46	21
12	8.01	0.16	16.6	10	0.45	21	20	59
13	7.88	0.16	17.8	35	0.85	35	46	19
14	7.88	0.13	24.3	35	0.55	33	48	19
15	7.90	0.15	22.0	27	1.03	35	48	17

[a]2:1 extract

Table 2 The amount of available potassium was estimated by the following methods

Extract No.	Extractants	Soil–solution Ratio	Equilibration Time (minute)	Reference
1	0.002 M $SrCl_2$	01:10	30	[20]
2	0.02 M $SrCl_2$ + 0.05 M citric acid	01:10	30	[20]
3	0.5 M $MgNO_3$	05:33	10	[25]
4	1 M NaCl	01:10	60	[14]
5	1M NH_4OAc	01:10	15	[9]
6	0.5M NH_4OAc	01:10	15	[18]
7	0.25M NH_4OAc	01:10	15	[1]
8	0.1M NH_4OAc	01:10	15	[14]

Greenhouse Experiment

A greenhouse experiment was carried out with the 15 soilsto determine the K uptake, K concentration, plant response andrelative yield to applied K.The soils were prepared for potting by air dryingand grinding to <2 mm. Five kilograms of each type of soils were put in 25 cm diameter pots, and arranged in a factorial experiment in a randomized complete block design with three replications and two rates of K applied as K_2SO_4 (0 and 200 mg kg^{-1}).To ensure an equilibrated plant nutrition level for supporting Pinto beans (Phaseolusvulgaris) growth, 100 mg kg^{-1}phosphorus (P) as $Ca(H_2PO_4)_2$, 5 mg kg^{-1}iron (Fe) as sequestrine, and 5 mg kg^{-1}zinc (Zn) as $ZnSO_4$ were added to soils. For nitrogen (N), 60 mg kg^{-1} urea was twice added to the soils.Bean (Var.pinto) seeds were planted and were grown under greenhouse conditions. The pots were irrigated daily, and moisture was maintained near field capacity. Ten weeks after sowing, the shoots of bean were harvested and separated for analysis. Plant samples were washed with distilled water and were oven dried at 70˚C with ventilation. After that, yields of dry matter were determined, and plant analysis for K was done after grinding by dry-ashing method. Plants indices including K uptake, the relative yield, and plant response were calculated by the following equations:

K uptake (mg per pot) = Yield of dry matter × K concentration

Relative yield (%) = (yield of dry matter of control pots / the yield of dry matter of treated pots) × 100

Plant response = Yield of dry matter of treated pots - Yield of dry matter of control pots

Statistical Analysis

Correlation coefficients wereused to assess the relationships among the extractants.Simple correlation coefficients were calculated between K extracted by chemical methods and plant indices. Significant correlation coefficient

Indicated efficiency of extractants. Finally, the K critical level for bean, extracted by better extractants, was determined by the Cate-Nelson (1971) method[4].

Results and discussion

Some selected physical and chemical properties of soil have beenshown in Table 1.The clay content varies from 21 to 53%, CEC between 15.5 and 24.3 Cmolc kg^{-1}, organic C content from 0.45 to 1.53%, the equivalent CaCO3 from 6 to 40%. The electrical conductivity ranged from 0.11 to 0.19 ds m^{-1}, and the pH from 7.74 to 8.10. Effects of K application on bean are shown in Table 3. Potassium application in most soils increased the dry matter yield, K uptake, and K concentration in bean significantly ($p<0.01$). This parameter indicates that in these soils, bean gives a remarkable response to K application.

Table 3 Effects of K application on bean dry matter, K uptake, and K concentration

Soil no.	Yield (g per pot)		K concentration ($g\ kg^{-1}$)		K uptake (mg per pot)	
	Treated	Blank	Treated	Blank	Treated	Blank
1	6.64^{a}	4.85^{a}	32.9^{a}	21.5^{b}	218^{a}	104^{b}
2	6.20^{a}	5.25^{b}	23.6^{a}	12.8^{b}	145^{a}	67^{b}
3	7.18^{a}	7.03^{a}	30.5^{a}	19.0^{b}	219^{a}	133^{b}
4	7.08^{a}	4.52^{b}	24.7^{a}	13.0^{b}	175^{a}	59^{b}
5	9.10^{a}	5.40^{b}	23.5^{a}	16.0^{b}	213^{a}	87^{b}
6	4.92^{a}	3.60^{b}	24.4^{a}	16.9^{b}	120^{a}	61^{b}
7	5.44^{a}	3.62^{b}	26.2^{a}	15.6^{b}	143^{a}	57^{b}
8	5.20^{a}	6.43^{b}	22.1^{a}	21.5^{a}	115^{a}	138^{b}
9	5.85^{a}	4.22^{b}	24.0^{a}	14.3^{b}	140^{a}	61^{b}
10	7.00^{a}	6.28^{a}	29.0^{a}	21.0^{b}	203^{a}	132^{b}
11	7.55^{a}	5.67^{b}	21.5^{a}	18.0^{b}	162^{a}	102^{b}
12	6.46^{a}	6.56^{a}	25.0^{a}	16.0^{b}	161^{a}	105^{b}
13	3.59^{a}	4.18^{a}	29.7^{a}	25.0^{b}	107^{a}	105^{a}
14	7.31^{a}	4.79^{b}	23.2^{a}	13.0^{b}	170^{a}	63^{b}
15	7.02^{a}	5.25^{b}	25.7^{a}	10.6^{b}	181^{a}	56^{b}

[a] *Each value was compared with its blank at the 0.05 level of significance*

Table 4Amount of K (mg/kg) availability indices of the soils studied

Soil no.	Extract 1	2	3	4	5	6	7	8
1	36	74	134	129	231	260	267	274
2	34	80	144	135	253	276	282	286
3	66	143	177	201	244	264	261	276
4	14	36	60	61	157	174	188	190
5	20	51	80	98	223	246	256	260
6	20	36	82	88	140	150	158	164
7	14	36	70	72	136	150	160	166
8	36	78	147	142	257	274	292	298
9	22	63	105	102	268	292	294	304
10	78	157	235	230	312	318	336	336
11	34	78	136	131	274	296	306	314
12	58	94	147	166	175	192	202	204
13	46	94	159	150	303	334	342	346
14	16	42	116	111	184	212	218	220
15	32	67	142	133	178	296	306	310
Mean	35	75	129	130	229	249	258	263

The mean available K of 15 soils extracted by 8extractants has beenshown in Table 4. The different extraction procedures' ability to extract K was in the following order: 0.002 M $SrCl_2$< 0.02 M $SrCl_2$ + 0.05 M citric acid <0.5 M $MgNO_3$< 1 M NaCl< 1 M NH_4OAc < 0.5 M NH_4OAc < 0.25M NH_4OAc < 0.1M NH_4OAc. Comparison of these soil K tests indicated that the lowest values (mean 35 mg kg^{-1}, ranged 14–78 mg kg^{-1}) were obtained by 0.02 M $SrCl_2$ extraction and the highest values(mean 263 mg kg^{-1}, ranged 164–346 mg kg^{-1}) were obtained by 0.1 M NH_4OAc. The results show that the concentrations of K extracted varied widely with the method used, because each extractant desorbed different portions of K.According to the mechanism of the extraction,these extractants can be classified in three groups. In the first group(acidic extractants), the mechanism of extracted K is displacement of K by hydrogen cation and includes 0.02 M $SrCl_2$+ 0.05 M citric acid. The mean K of soils extracted by 0.02 M $SrCl_2$ + 0.05 M citric acid ranged from 36 to 157mg kg^{-1}.This extractant removes solution and partly exchangeable K.In the second group, mechanism of K extracted is displacementof K by nonsimilarcations and includes 1 M NaCl, 0.5 M $MgNO_3$, and 0.002 M $SrCl_2$.The mean K of soils extracted by 1 M NaCl, 0.5 M $MgNO_3$, and 0.002 M $SrCl_2$ ranged from 61 to 230, 60 to 235and 14 to 78mg kg^{-1}, respectively.These results showed that K of soils extracted depends on soil and extractants characteristics. The difference of K between soils was attributed to type of clay minerals, clay and silt contents of soils.In the third group, the mechanism of K extracted is displacementof K by similar cation and includes 1 M NH_4OAc, 0.5 M NH_4OAc, 0.25M NH_4OAc,and 0.1M NH_4OAc.The mean K of soils extracted by 1 M NH_4OAc, 0.5 M NH_4OAc, 0.25M NH_4OAc, and 0.1M NH_4OAc ranged from 136 to 312, 150 to 334, 158 to 342 and 164 to 346mg kg^{-1}, respectively. Among of Ammonium Acetate at different concentrations, 0.1 M Ammonium Acetate extractantextracted the highest amount of K (mean 263mg kg^{-1}) and 1 M Ammonium Acetate removed the lowest amount of K (mean 229mg kg^{-1}).The difference of K extracted between these methods was attributed to the concentration of extracting.These extractants desorbed solution, exchangeable and partly non-exchangeable K.The correlation coefficients between K extracted by these chemical methods are shown in Table 5.In the second group, the correlation coefficients were statistically highly significant between 0.002 M $SrCl_2$, and 1 M NaClextractants for determination of potassium.No relationship was found between 0.5 M $MgNO_3$and 0.002 M $SrCl_2$extractant.The amounts of K extracted by 0.5 M $MgNO_3$ was significantly correlated with those extracted by 1 M NaClextractant.In the third group, the result indicated that the amounts of K extracted by 1 M NH_4OAc, 0.5 M NH_4OAc, 0.25M NH_4OAc, and 0.1M NH_4OAc were highly correlated with each other. This suggests that similar K fractions (solution, exchangeable and partly non-exchangeable K) were determined by theseextractantsin this group. Therefore,among of Ammonium Acetate at different concentrations, 0.1 M Ammonium Acetateextractant can be used inorder to reduce operating costs.The relationships between different potassium-availability indices and potassium uptake by plant are called correlation studies. Also in correlation studies, the relationships between different potassium availability indices and K concentration, additional K uptake, yield, relative yield, plant response, and increase of K concentration are in consideration.The relationship between the amounts of extracted K was linearly related to plants indices (Table 6).The K uptake of bean was best predicted by the amount ofK extractedby 0.002 M $SrCl_2$($r = 0.79$), 0.02 M $SrCl_2$ + 0.05 M citric acid ($r = 0.79$),0.5 M $MgNO_3$ ($r = 0.57$), and 1 M NaCl($r= 0.79$). The correlation coefficients were observed between 0.002 M $SrCl_2$, 0.02 M $SrCl_2$ + 0.05 M citric acid, and 1 M NaClwith plant response in plants (-0.61, -0.56, and -0.59 respectively) and with relative yield in plants (0.63, 0.58, and 0.61 respectively). Potassium extracted by 0.002 M $SrCl_2$extractant was significantly correlated withK concentration in plants.No relationship was found between K uptake of crops and K^+ extracted by Ammonium Acetate at different concentrations, which extract solution, exchangeable and partly non-exchangeable K in these soils. Exchangeable potassium is absorbed on soil colloid surfaces and is available to plants; however, plants obtain most of their potassium from the soil solution.Wanasuria et al. (1981) found that NH_4OAC extractable K was not significantly correlated with rice yield response to K fertilizers[26]. Wang et al. (2010) found that NH4OAC method was only suitable for evaluating K availability in soils with similar K-buffering capacity, but was not suitable for evaluation of K availability in soils with different K-buffering capacities[27].The inadequacy of the NH_4OAc soil test has been clearly demonstrated in illitic[13]and vermiculitic soils[3].

Table 5 Correlation coefficients between K extracted by 8 extractants

Extr.\Extr.	2	3	4	5	6	7	8
1	0/97^{a}	0/46^{ns}	0/97^{a}	0/54^{b}	0/50^{ns}	0/50^{ns}	0/50^{ns}
2		0/55^{b}	0/97^{a}	0/65^{a}	0/61^{b}	0/60^{b}	0/61b
3			0/52^{b}	0/75^{a}	0/74^{a}	0/76^{a}	0/75^{a}
4				0/63^{b}	0/60^{b}	0/60^{b}	0/60^{b}
5					0/99^{a}	0/99^{a}	0/99^{a}
6						0/99^{a}	0/99^{a}
7							0/99^{a}

[a]Significant at p=0.05. [b]Significant at p=0.01. [ns]Not significant at p=0.05

Table 6 Correlation coefficient between K extracted by 8 extractants and plant Indices

Extr. no.	K uptake	K concentration	Plant response	relative yield
1	0/79 ^{a}	0/52 ^{b}	-0/61 ^{b}	0/63 ^{b}
2	0/79 ^{a}	0/50 ^{ns}	-0/56 ^{b}	0/58 ^{b}
3	0/57 ^{b}	0/48 ^{ns}	-0/31 ^{ns}	0/49 ^{ns}
4	0/79 ^{a}	0/48 ^{ns}	-0/59 ^{b}	0/61 ^{b}
5	0/49 ^{ns}	0/39 ^{ns}	-0/34 ^{ns}	0/44 ^{ns}
6	0/47 ^{ns}	0/39 ^{ns}	-0/32 ^{ns}	0/43 ^{ns}
7	0/48 ^{ns}	0/40 ^{ns}	-0/32 ^{ns}	0/44 ^{ns}
8	0/49 ^{ns}	0/41 ^{ns}	-0/33 ^{ns}	0/44 ^{ns}

[a]Significant at p=0.05. [b]Significant at p=0.01. [ns]Not significant at p=0.05

Potassium extracted by 0.002 M $SrCl_2$, 0.02 M $SrCl_2$ + 0.05 M citric acid, and 1 M NaClextractants was significantly correlated with plant indices. So it can be concluded that 0.002 M $SrCl_2$, 0.02 M $SrCl_2$ + 0.05 M citric acid, and 1 M NaClextractants, would be suitable as soil testing producers for determining bean available K of these soils.These results are in agreement with those reported by Hosseinpur and Sinegani[10],Simard and Zizka[21],andHosseinpur and Samavati[11].Hosseinpur and Samavati (2008) found that 0.002 M $SrCl_2$, and 0.02 M

$SrCl_2$ + 0.05 M citric acidextractants, were suitable for evaluation of K availability for corn[11].A good soil test should be able to predict the amount of plant available K as well as the fertilizer responsiveness of a plant growing on a wide range of soils. Prediction of plant response to fertilizers is traditionally determined by Cate-Nelson graphic method. The relationship between the relative yield of bean and the amount of soil K extracted by the suitable chemical methods are shown in Fig.1 The critical concentration of K determined by the various extraction procedures were obtained using the graphical method of Cate and Nelson [4], and were 38, 80, and 136 mg kg^{-1} for 0.002 M $SrCl_2$, 0.02 M $SrCl_2$ +0.05 M citric acid, and 1 M NaCl, respectively.

CONCLUSION

The usefulness of an extraction method for soil K depends on its ability to explain the variation in K uptake and response to fertilizer by plants grown in soils where the amounts of available K as well as other properties vary considerably. This study shows that 0.002 M $SrCl_2$, 0.02 M $SrCl_2$ +0.05 M citric acid, and 1 M NaCl would be suitable as soil testing Methods for determining available K to bean, particularly 0.02 M $SrCl_2$ + 0.05 M citric acid extractant. It can be concluded that easily extractable forms of K (water soluble and exchangeable) play an important role in predicting bean-available K in these soils.

Although 1 M NH_4OAC procedure is used to assess the K availability to crops in ChaharMahal and Bakhtiari soils, the results of the present study showed that Ammonium Acetate at different concentrations cannot be used as soil testing Methods for determining K to bean.

The 0.02 M $SrCl_2$ + 0.05 M citric acid solution can be used as a single extraction in soil test laboratoriesfor determination of the complete nutrient status of a soil in order to increase efficiency and to reduce operating costs.It has been reported that 0.02 M $SrCl_2$ + 0.05 M citric acid solution was good indices for K, N, and P availability [20, 19, 21]. But this procedure, sameas others, needs further evaluation for elements other than K in a wide range of soils and plants, and would require calibration under field conditions.

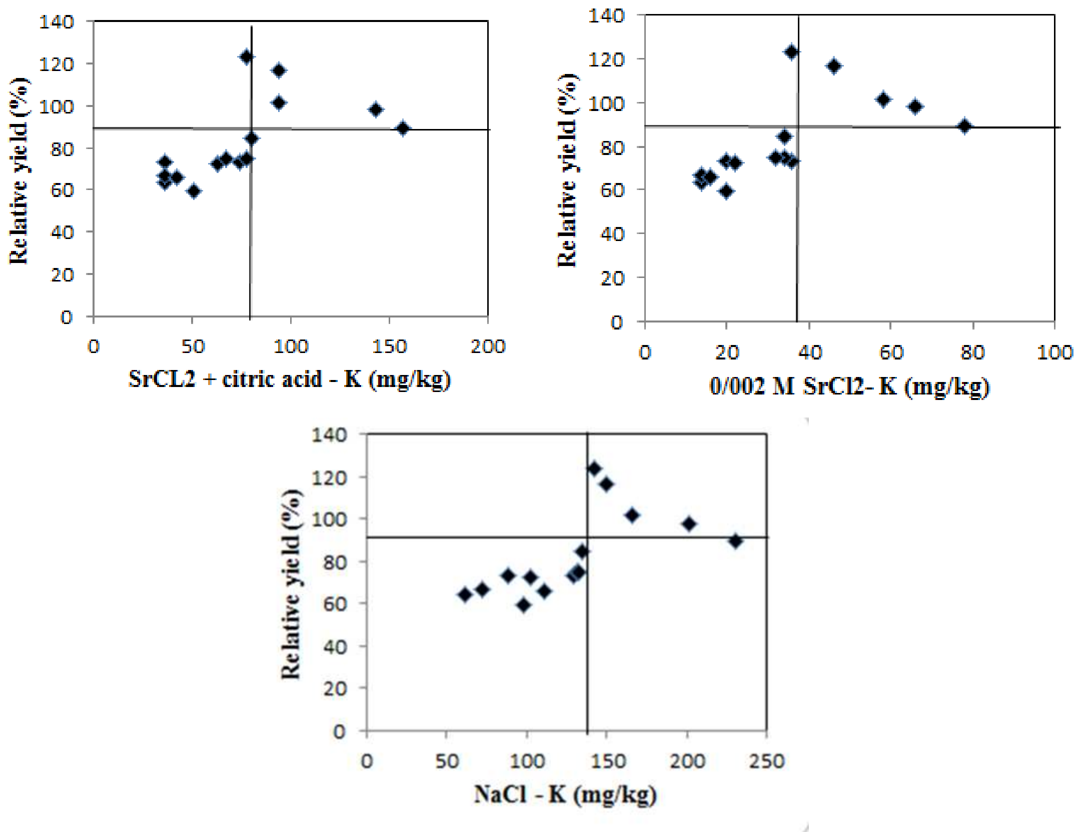

Figure 1. Cate-Nelson plot and potassium critical levels in suitable extractant

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