Comparison of AB-DTPA Method with the Standard Methods for Extractable P and K from Prominent Soils of Potohar Region, Pakistan

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Summary: A number of tests have been conducted for the determination of plant available P and K in the soil. A study was conducted to compare and correlate P and K extracted through the AB-DTPA method with Olsen's reagents sodium bicarbonate ($NaHCO_3$) for P and ammonium acetate (NH_4OAc) for K from a prominent soil series of Potohar region, Pakistan. Thirteen soil series, developed from variable parent materials having different texture and chemical properties were selected for this study. The P and K extracted from AB-DTPA from these soils were correlated with $NaHCO_3$ and NH_4OAc respectively. The results showed a positive correlation between the AB-DTPA and $NaHCO_3$ extractable P (r = 0.936) and NH_4OAc extractable K (r = 0.986). Moreover, the cost of chemicals involved in the extraction of P and K also supported the idea that AB-DTPA is economical and cost effective. Hence, it was concluded that AB-DTPA extractant can be used for the determination of P and K in the soils of Potohar region.

Introduction

Soils in the plains of Pakistan are formed from alluvium deposited by the Indus River and its tributaries [1, 2]. The soils of Potohar Plateau have been derived from diverse parent materials and are loess, alluvial, colluvial and mixed in nature. Most of the soils belong to Inceptisols, Entisols and Aridisols and to a small extent, Alfisols are also present [3]. The soils of the Potohar Plateau are prone to both water and wind erosion because of the undulating land-forms. Owing to their variable chemical composition, release and fixation capacity of P and K of these soils vary to a considerable extent. In Pakistan, commonly used methods for assessing plant "available" P and K from soil are: 0.5*M* $NaHCO_3$ for P [4], 1*N* ammonium acetate for K [5-7] and ammonium bi-carbonate diethylene triamine penta-acetic acid (AB-DTPA) [8-9]. The AB-DTPA test has the advantage to extract macro and micronutrients from alkaline soils in a single extraction. This extracting reagent is a combination of 1*M* NH_4HCO_3 and 0.005*M* DTPA. The NH_4^+ ions in the solution replace exchangeable cations, like Na, K, Ca and Mg as well as the micro-nutrients e.g., Fe, Zn, Cu, Mn etc. Diethylene tri-amine pentaacetic acid (DTPA) chelates cations such as Zn, Fe, Cu, Mn, Pb, Ni, and Cd and thus provides availability or toxicity indices for these elements. This method correlated well with Mehlich-III for $NaHCO_3$ extractable P and NH_4OAc extractable K [10]. This method was tested for 481 soils with diverse chemical characteristics and it was proven that it correlated well with 0.5*M* $NaHCO_3$ for P [11]. The AB-DTPA soil test was compared with three methods, $NaHCO_3$, Mehlich-III and modified Olsen's method for 31 soils of Pakistan, and found correlated with $NaHCO_3$ for the extraction of P with r = 0.97 [12].

Extraction of P and K from soil, by 0.5*M* $NaHCO_3$ and 1M NH_4OAc, is time consuming and is also toiling in nature, whereas AB-DTPA method is rapid and less laborious. Moreover, macro and micro-nutrients can be determined in a single extraction. Recently, the micronutrients determination has attained a lot of attention and the soil testing laboratories of Punjab, Pakistan, is considering this issue seriously for soil advisory services in future. In addition to N, P and K, micronutrient deficiencies e.g. Zn, B and Fe are also becoming widespread [13]. Soil testing advisory services may soon initiate analyzing farmer's soil samples for micronutrient as well. Thus, exploring new soil test methods for this purpose is the need of the hour. A lot of work on comparison and correlation of AB-DTPA and $NaHCO_3$ soil tests method, for plant available P, has been reported, but no work on the comparison and correlation of AB-DTPA with NH_4OAc soil test for K has been reported, especially for the soils of Potohar areas. Keeping in view these facts,

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comprehensive study was conducted with the following objectives:

To compare and correlate AB-DTPA extractable P and K with $NaHCO_3$ and NH_4OAc extractable P and K respectively.

To explore the feasibility of the adoption of AB-DTPA method in soil testing laboratories of Pakistan.

Results and Discussion

The results pertaining to the extractable P from soil are presented in Table-1. The soil AB-DTPA extractable P ranged from 0.13 to 6.18 mg kg^{-1} in different soils. Maximum value of 6.18 mg kg^{-1} was observed in Kahutta soil, followed by Balkassar and Guliana. In the case of $NaHCO_3$, the amount of P extracted from soils ranged from the minimum of 0.29 mg kg^{-1} in Tirnaul soil to a maximum of 13.81 mg kg^{-1} in Balkassar soil. The AB-DTPA extracted less P from all soils under the study as compared to $NaHCO_3$. The differences were more pronounced in the soils with high P level compared to low P levels. Further the P extracted was low in the majority of the soils.

Table-1: Comparison of two extractants used for P extraction from soils

Soil	Extractable P (mg kg^{-1} of soil)	
	$NaHCO_3$	AB-DTPA
Talagang	4.99	1.50
Therpal	5.37	1.42
Bahtar	3.10	1.29
Basal	4.32	1.67
Chakwal	3.11	1.25
Guliana	9.30	3.97
Missa	0.29	0.13
Rajar	0.45	0.21
Satwal	11.79	4.42
Balkassar	13.81	4.72
Kahutta	10.34	6.18
Khaur	3.26	1.21
Tirnaul	0.29	0.17

According to the criteria [9], soils having AB-DTPA extractable P less than 4 mg kg^{-1} are regarded as deficient, 4 to 7 mg kg^{-1} as marginal and greater than 8 mg kg^{-1} as adequate for plant growth. As per these criteria, Kahutta soil was found to be marginal in available P, while all other soils were deficient. In case of $NaHCO_3$ extraction, a soil containing less than 8 mg kg^{-1} extractable P was ranked as deficient or low, with values 8 to 15 mg kg^{-1} as marginal, and greater than 15 mg kg^{-1} as adequate [4]. According to these criteria, out of the thirteen soils, ten were deficient and three, Balkassar, Satwal and Guliana soils, were in marginal range of available P.

The correlation analysis showed a positive correlation between the amounts of P extracted by both the methods i.e. r = 0.936 (Fig. 1, Table-2). Both of these extractants extracted P and the amounts extracted were positively correlated with each other. In both the extractants, (HCO_3), an active ingredient reacted with Ca present in the soil precipitates it as $CaCO_3$ that otherwise would bind with P in the form of chemical complexes like di-calcium and tri-calcium phosphate. As a result, P was released in the solution. It could be confirmed by high suggested pH level of $NaHCO_3$ extractant (pH of 8.5) as compared to AB-DTPA (pH 7.6) that resulted in quick $CaCO_3$ precipitation and a release of greater amount of P from soil by $NaHCO_3$ extractant [4, 9]. The difference in duration of the reaction, that is the shaking time given to the extractants, might be another reason for low P extraction with AB-DTPA. In the $NaHCO_3$, soil was shaken for 30 minutes,

Table-2: Correlation between soil extractable P and soil properties

Soil Properties	Extractable P	
	AB-DTPA	$NaHCO_3$
$NaHCO_3$ P	0.936	-
Clay (g $100g^{-1}$)	0.494	0.566
Silt (g $100g^{-1}$)	-0.798	-0.758
$CaCO_3$ (g $100g^{-1}$)	-0.712	-0.762
Organic Matter (g $100g^{-1}$)	0.535	0.541
HCO_3 (me L^{-1})	0.414	0.535

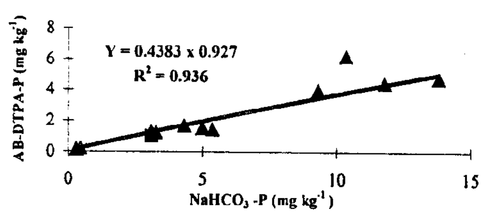

Fig. 1: Correlation between AB-DTPA and $NaHCO_3$ extractable-P from soils.

while in the case of AB-DTPA, the soil was shaken for 15 minutes only [4, 9]. Further, the quantity of soil and the extractant taken for extracting P also varied. In $NaHCO_3$ method, 5 g soil was taken in 50 ml of extractant and the ratio between soil and extractant was 1:10 [4], while in AB-DTPA method 10 g soil was extracted with 20 ml of extractant and the ratio between soil and extractant became 1: 2 which was narrow [9]. In this case, more quantity of the extractant remained in contact with soil for longer time that resulted in higher P extraction from the soils as compared to smaller quantity for shorter period of time in case of AB-DTPA extractant. This may also be the cause for more P extraction from the soils with $NaHCO_3$ as compared to AB-DTPA extractant. Although the AB-DTPA extracted less P as compared to $NaHCO_3$, yet they correlated well with each other (Table-2). The AB-DTPA method has also been tested for 481 soils, having diverse chemical characteristics and proven that it correlated well with 0.5*M* $NaHCO_3$ for P [8, 14]. In another study [12], AB-DTPA method was compared with $NaHCO_3$ for 31 soil samples for P extraction and results had shown that these methods correlated well with each other (r = 0.97).

Correlation of AB-DTPA and $NaHCO_3$ P with Soil Properties

The amount of P extracted with AB-DTPA and $NaHCO_3$ not only positively correlated with each other but also with the soil properties as well. The amounts of P extracted with extractants from the soils, correlated with clay, organic matter, bicarbonate (HCO_3) and $CaCO_3$ in the soils with correlation co-efficient r = 0.494, 0.535, 0.414 and -0.712 respectively for AB-DTPA-P and r = 0.566, 0.541, 0.535 and -0.762, for $NaHCO_3$ concurrently (Table-2). The $CaCO_3$ present in soils had negative correlation with the amount of P extracted with both the extractants. These indices showed that less P becomes available in soils with more $CaCO_3$ as it reacts with Ca present in the soil and makes complexes and converts P into insoluble and unavailable forms like di-calcium phosphate and tri-calcium phosphate etc. [15].

Three types of trends appeared in the amounts of P extracted with the extractants: (1) in low P soils, the ratio between the amounts extracted from soils with both the extractant was 1:2; (2) in the soils having extractable P in marginal range, the ratio was 1: 3; and (3) in the soils with marginal to adequate P, the ratio between the amount of P extracted by both the extractants was wider than 1: 3, like Balkassar and Satwal soils. This point however needs further elaborative investigations. Fig. 1 indicates point to point relationship between the P extracted from soils and extractants.

Comparison of Extractants Used for K Extraction from the Soils

Two chemical extractants namely AB-DTPA and NH_4OAc were tested for potassium extraction from soils. The amounts of K extracted with AB-DTPA were compared with those of NH_4OAc extractant. The results depicted that AB-DTPA extractable-K was the maximum in Satwal soil followed by Therpal and Talagang soils (Table-3). According to soil critical levels for AB-DTPA extractable K, three soils were deficient, six were in marginal range and four soils had adequate quantities of K whereas according to NH_4OAc extractable K sufficiency criteria, six soils were deficient, four were in marginal range and three had adequate K levels. The results of the study are in line with those reported by [16, 9 17]. They stated that the soil having AB-DTPA extractable K value less than 60 mg kg^{-1} is marked as deficient, the one with a value in the range of 60 to 120 mg kg^{-1} designated as marginal and > 120 mg kg^{-1} of soil as adequate for plant growth. In the case of NH_4OAc extraction, if a soil contained less than 100 mg extractable K, kg^{-1} soil, it was ranked as deficient, with values 100 to 150 mg kg^{-1} it was marginal and >150 mg kg^{-1} it was adequate. The amount of K extracted with AB-DTPA was lower than that extracted through NH_4OAc. The K extracted with both the extractants was strongly correlated with each other having correlation coefficient of r = 0.986, (Table-4). This indicates that both the extractants could be used for evaluation of the K level of the soils.

Table-3: Comparison of two extractants used for K extraction from soils

Soil	Extractable K (mg kg^{-1} of soil)	
	NH_4OAc	AB-DTPA
Talagang	154	128
Therpal	178	146
Bahtar	118	94
Basal	104	97
Chakwal	126	120
Guliana	100	92
Missa	66	56
Rajar	72	62
Satwal	288	236
Balkassar	68	60
Kahutta	86	52
Khaur	96	90
Timaul	58	50

NH_4OAc extracted relatively higher amounts of K as compared to AB-DTPA. This was probably due to the presence of higher concentration of NH_4^+ ion in NH_4OAc than in AB-DTPA and the time of extraction. Ammonium ions are known to efficiently

Table-4:Correlation between extractants used for K extraction and soil properties

Soil Properties	Extractable K	
	AB-DTPA	NH_4Oac
NH_4OAc – K	0.986	1
Clay (g 100 g^{-1})	0.741	0.807
HCO_3 (g 100 g^{-1})	0.662	0.627
$CaCO_3$(g 100 g^{-1})	-0.272	-0.315
OM (g 100 g^{-1})	0.602	0.633
CEC ($cmol_c$ kg^{-1})	0.734	0.681

replace exchangeable K as well as K from specific sites. The quantities of K displaced with both the extractants were significantly correlated with each other. As in both the extractants, active component for K displacement from clay lattice was NH_4^+, which knocked out K present at the clay lattice in soil. This cation exchange reaction takes place between the soil solution and soil, yielding K, which is measured by flame photometer and used for the assessment of its status in soil. The other reason might be the quantity of soil and extractant taken for extracting K. In NH_4OAc 5 g, soil was taken in 50 ml of extractant and the ratio of soil to extractant was 1: 10, while in AB-DTPA, 10 g soil was extracted with 20 ml of extractant, the ratio of soil to extractant was 1: 2 which was a narrow one. Two type of trends appeared between the amounts of K extracted from the soils with both the extractants: (1) for soils with low to adequate K, the ratio between K extracted with extractants was 1: 1 and (2) for the soils with adequate to high K levels, the ratio was about 1: 1.5 (Fig. 3).

Correlation Between K Extractants and Soil Properties

The soil properties play an important role in the availability of K to crops. For example, for the soil with greater amount of clay and adequate cation exchange capacity (CEC), the K applied can or can not be available to the crop, because it may partially be fixed in clay and supplied K only fulfills the soil hunger, thereby the plant can not have access to the applied K. The amounts of K extracted had a positive correlation with soil properties like clay, CEC, organic matter and bicarbonates in soil. Moreover, soil extractable K had negative correlation with silt and $CaCO_3$ contents in the soils (Table-4). The regression analysis showed that the release rate constant value (Kr) estimated by power function equations was highly and positively correlated with the clay (r = 0.652 and 0.470), HCO_3 (r = 0.507 and 0.456); CEC (r = 0.681 and 0.734) and OM (r = 0.633 and 0.615) for NH_4OAc and AB-DTPA extractable K, respectively. Available K of different districts of Potohar ranged from 150 to 389 mg kg^{-1} with a standard deviation of 3.6 to 132.3. On the basis of 14 year of data, they concluded that 8.8 mg K kg^{-1} soil is being depleted annually from soils by crop removal [18].

Feasibility for Adoption of AB-DTPA Soil Test in Pakistan

The results of the study showed that the amount of P and K extracted with AB-DTPA method strongly correlated with that extracted by $NaHCO_3$ and NH_4OAc having a correlation coefficient r = 0.936 and 0.986 for P and K, respectively. The soil extractable P and K also correlated with soil properties. The soils under investigations had variable parent material, physical and chemical properties, and the AB-DTPA test method had good correlation for P and K extraction with routine methods of $NaHCO_3$ and NH_4OAc (Fig. 2). This indicates that AB-DTPA can be used for evaluating

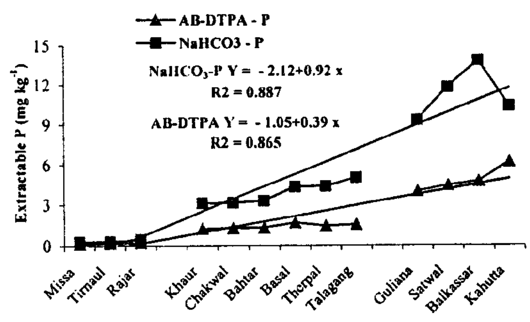

Fig. 2: Point to point relationship between AB-DTPA and $NaHCO_3$ extractable-P from soils.

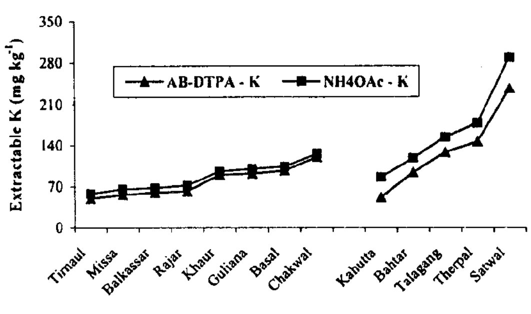

Fig. 3: Point to point relationship between AB-DTPA and NH_4OAc extractable K from soils.

Table-5: Comparison of cost of extractants used for P and K extraction from soils

Particulars	Extractant					
	For P			For K		
	$NaHCO_3$	AB	DTPA	AB	DTPA	NH_4OAc
Chemical used (g/ L)	42.01	79.06	1.97	79.06	1.98	77.1
Cost of chemical/ g (Rs.)	135.00	149	616.00	149.0	-	296.0
Total cost of chemical (Rs.)	5672.00	11780.0	1214.00	Same as for P		2284.0
Extractant used/ sample (ml)	50	20		20		50
Samples can be determined/ L solution	20	50		50		20
Cost / sample (Rs.)	285.00	270.00		Same as for P		120.00
Color developing reagent cost (Rs.)	10.00	10.00		-		-
Total cost/sample (Rs.)	295.00	280.00		-		120.00

Table-6: Physical characteristics, classification and parent material of soils selected for the study

Soils	Clay	Silt (g $100g^{-1}$)	Sand	Text. Class	Great Group	Order	Parent Material
Talagang	8.5	31.5	60.0	Sandy loam	Ustochrept	Inceptisol	Alluvium
Therpal	23.5	69.0	7.5	Silt loam	Camborthid	Aridisol	Alluvium
Bahtar	18.5	71.5	10.0	Silt loam	Ustorthents	Inceptisol	Loess
Basal	11.0	49.0	40.0	Loam	Ustochrept	Entisol	Loess
Chakwal	6.0	71.5	22.5	Silt loam	Haplargid	Aridisol	Loess
Guliana	12.5	42.5	45.0	Loam	Hapalustalf	Alfisol	Loess
Missa	8.5	74.0	17.5	Silt loam	Ustocrept	Inceptisol	Loess
Rajar	6.0	91.5	2.5	Silt	Ustorthent	Entisol	Loess
Satwal	36.0	39.0	25.0	Clay loam	Chromurtert	Vertisol	Loess
Balkassar	13.5	39.0	47.5	Loam	Hapalustalf	Alfisol	Residuum (sandstone)
Kahutta	17.0	21.9	61.1	Sandy loam	Hapalustalf	Alfisol	Residuum (sandstone)
Khaur	13.5	71.5	15.0	Silt loam	Ustochrept	Inceptisol	Residuum (shales red and purple)
Tirnaul	8.5	59.0	32.5	Silt loam	Ustochrept	Inceptisol	Residuum, Colluvial (shales)

the soil P and K level under Pakistan soil conditions. As this method had been tested and compared with different methods for P extraction in Pakistan and many scientists have verified AB-DTPA test for P extraction and it had been proven that it could be safely used for P evaluation under Pakistan soil condition, it is in good agreement with $NaHCO_3$ soil test as advocated by [12, 19-21]. But comparative studies for P under rainfed soil conditions and for K extraction by AB-DTPA and NH_4OAc methods were not undertaken before this study. So it has been proved that AB-DTPA soil test also correlated with NH_4OAc K extraction under Pakistan soil conditions. The cost of extraction involved for P and K extraction methods was also worked out (Table-5): clearly shows that AB-DTPA is cost effective, economical, time saving, and we can determine macro and micro nutrients in a single extraction from soils. The studies indicated that this method could be used for soil P and K evaluation for advisory and research purposes in the country.

Experimental

Soil Sampling and Analysis

Two composite soil samples from 0-15 cm depth were collected from each of the thirteen soils of Potohar Plateau, Pakistan. The soil series were; Bahtar, Balkassar, Basal, Chakwal, Guliana, Kahutta, Khaur, Missa, Rajar, Satwal, Talagang, Tirnaul and Therpal. Samples were air dried ground with a wooden pestle and mortar, sieved through 2 mm sieve and characterized for physical and chemical properties. Soil characteristics like pH, EC_e, HCO_3 were determined by using the standard procedure [22], CEC as reported by [23], organic matter and calcium carbonate by [24], and the soil NO_3-N was determined by hydrazine reduction method [25].

Laboratory Investigations

The majority of the soils were loess, followed by residuum in nature and most of the soils were loam in texture. However, the percentages of clay (6 to 36 %) and sand percentage (2.5 to 61.5 %) varied greatly in these soils (Table-6). The soils were normal to alkaline in reaction with pH ranging from 7.6 to 8.21 and EC_e varied from 0.25 to 2.9 dS m^{-1}. The soils were low in AB-DTPA extractable NO_3-N; $NaHCO_3$-P ranged from 0.29 to 13.81 mg kg^{-1} and NH_4OAc -K from 58 to 288 mg $kg^{-1}$of soil (Table-7). Organic matter contents were < 1 g 100 g^{-1} of soil in all the soils except Satwal soil that had OM of 1.10 g 100 g^{-1}. Calcium carbonate also varied and it was low

Table-7: Chemical characteristics of the soils selected for study

Soils	pH	EC_e (dS m^{-1})	HCO_3 (meL^{-1})	Cl	NO_3-N (mg kg^{-1})	P*	K**	$CaCO_3$ (g 100g^{-1})	OM	CEC (cmol$_c$ kg^{-1})
Talagang	7.80	0.52	2.84	3.33	2.20	4.99	154	3.80	0.50	20.00
Therpal	7.80	0.33	3.00	2.50	1.99	5.37	178	0.20	0.99	41.04
Bahtar	7.60	0.41	3.00	2.33	0.73	3.10	118	8.80	0.81	34.78
Basal	8.11	1.33	3.00	2.42	1.89	4.32	104	0.30	0.68	31.74
Chakwal	7.97	0.82	3.17	4.67	2.74	3.11	126	13.75	0.92	44.78
Guliana	7.70	2.90	2.84	4.75	1.82	9.30	100	0.52	0.92	27.48
Missa	7.91	0.76	1.50	2.50	5.90	0.29	66	14.30	0.57	32.17
Rajar	8.11	0.25	2.00	2.17	1.51	0.45	72	13.20	0.58	33.48
Satwal	7.80	0.35	3.32	2.25	2.22	11.79	288	2.45	1.10	53.91
Balkassar	8.21	0.48	2.83	2.34	1.72	13.81	68	0.75	0.70	26.52
Kahutta	7.70	0.63	2.50	3.09	1.55	10.34	86	0.06	0.87	19.57
Khaur	7.80	0.38	3.00	1.92	1.88	3.26	96	6.30	0.47	36.09
Tirnaul	7.70	0.68	1.50	2.50	2.45	0.29	58	9.50	0.58	24.35

* $NaHCO_3$ extractable P ** NH_4OAc extractable K, OM =Organic Matter CEC = Cation Exchange Capacity

in Balkassar, Basal, Guliana, Kahutta and Therpal soils and high in Chakwal, Missa, Rajar and Tirnaul soils CEC of the soils varied from 19.57 to 53.91 cmol$_c$ kg^{-1} soil.

The $NaHCO_3$ and NH_4OAc extractants were used for P [4] and K [6] extraction from the soils respectively, while AB-DTPA [26] for P and K both. The extracted P was measured colorimetrically [27]. Potassium extracted with AB-DTPA and NH_4OAc was determined by flame photometer [6]. The amounts of P extracted from soils by both extractants were correlated with each other. Similarly, the K extracted from soils was also correlated with each other according to procedures given by [28]. Computer software, Excel program, was used for computation of correlation.

Conclusions

The study led to the following conclusions:

The amounts of P and K extracted through AB-DTPA positively correlated with $NaHCO_3$ for P ($r = 0.936$) and K extracted with NH_4OAc ($r = 0.986$) as well as with soil properties except for the negative correlation with $CaCO_3$ contents of soils. Both the extractants can be used for assessing plant available P and K status of Potohar soils having variable parent material.

Three types of trends appeared in the amount of P extracted with both the extractants from the soils;

For the soils with low P, the ratio AB-DTPA and $NaHCO_3$ was 1:2;

For the soils having marginal P, the ratio was 1:3; and

For the soils with adequate P, the ratio was greater than 1: 3.

The amount of K extracted with both the extractants was greater in the soils derived from alluvium like Talagang and Therpal soils. The loess soils (except Satwal) had lesser quantities of K as compared to alluvial soils, whereas the soils derived from residuum followed the alluvial and loess soils.

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