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Short Communication

Contribution of Different Particle Size Fractions towards Potassium Nutrition in Pearl Millet and Wheat

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Very often it is observed that soils being deficient in available K (NH_4OAc extractable) do not respond to K application. It has been demonstrated that potassium from the reserve or mineral fraction becomes available over a period of time in response to plant removal and meet the excess K requirement. The reserve potassium involved in the replenishment processes of available K during the growing period mainly released from the clay micas (Datta and Sastry 1993; Pal and Durge 1993) and hence a fine textured soil shows better K supplying power. However, there is evidence of lack of response to applied K in coarse textured soils also (Sedusky *et al.* 1986; Pasricha 2002). In soils, reserve K is distributed in various K bearing minerals over the whole range of particle sizes from clay to sand and soil containing appreciable quantities of K bearing minerals in the coarse fraction may be an important source of K for plant. Therefore, knowledge on the contribution of each individual particle size class towards K nutrition in plant is essential to assess the actual K supplying power of a soil. With this objective, the present investigation was conducted to quantify the role of each particle size class in six different soils of two agro-climatic regions towards K nutrition in pearl millet and wheat in a pot-culture experiment.

All the six soils employed in this study were collected from the alluvial belt of India. Out of the total six samples, three soils (Palwal, Sonepat and Karnal) were taken from the semi-arid Yamuna alluvial plain, Haryana and the remaining three were collected from the humid Brahmaputra valley of Assam. Each sample from the two agro-climatic regions was selected in such a way that they represent three textural groups, namely light, medium and medium heavy. Soils were sampled from the sub-surface horizon in order to minimize the interfering factors like effect of addition of manures and fertilizers, presence of high organic carbon *etc.* Samples were processed (<2 mm) and analyzed for pH (1:2.5 soil water suspension), CEC, EC, organic carbon and NH_4OAc-extractable K, following the standard procedures (Jackson 1973). Non-exchangeable K was measured according to the procedure described by Knudsen *et al.* (1982) and total K with $HF-HClO_4$ digestion method (Lim and Jackson 1982). Mineral K was calculated as the difference between the total and HNO_3 extractable K. Potassium in all the filtered extracts was measured by an Elico model digital flame photometer.

The different particle size (mm) groups *i.e.* sand (2-0.05), silt (0.05-0.002) and clay (< 0.002) were quantitatively separated by gravity sedimentation technique (Jackson 1986). Non-exchangeable and mineral K of the different size groups was measured following the same procedures employed for "whole soil". To identify the prime K bearing minerals, sand and silt fractions were separately ground in agate mortar and pastle and random powder X-ray diffractograms were obtained. The X-ray diffraction pattern of clay fraction was obtained from basally oriented specimens for five different treatments (Mg-saturated air-dried, Mg-glycerol solvated, K air dried, K-300 ^{0}C and K-550 ^{0}C) using a Phillip diffractometer with Ni filtered Cu-Kα radiation. Semi-quantitative estimation of K bearing minerals was done as per the procedure of Gjems (1967).

To determine the contribution of each individual particle size groups to K nutrition, two crops of pearl millet (var. HHB-94) and wheat (var. HD-2009) were grown in small size polyethylene lined pots of 0.5 kg capacity containing 250 g ground soil and 150 g inert material (acid washed, sterilized 3-5 mm size stone particles). First, pearl millet was grown in the pots.

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Plants were maintained up to 40 days and then removed completely from the pots very carefully without any loss of soil. Plant samples were kept for K determination. In this way another three crops of pearl millet and two crops of wheat were grown for 40 days in the same pots. Plant samples were kept for K determination as above. During the whole experimental period, plants were supplied with deionised water and nutrient solution without K. The dry matter yield for each batch of crop was recorded. Potassium concentration in the dried and ground plant samples was determined (Jackson 1973). At the end of the experiment, 50-100 g soil was taken out from each of the pots and soils of different particle sizes were separated following the procedures as described earlier. Different forms of K in "whole soil" and in individual size groups were also determined.

The important physico-chemical properties of the soils, along with their taxonomical classification, are presented in table 1. Soils of Palwal (semi-arid) and Jorhat (humid) contained comparable quantity of sand, silt and clay. Similar relationship was also maintained between Sonepat and Kokila and Karnal and Chatia soils. However, in respect of other properties such as pH, EC, CEC, there were differences between the two regions. Soils of semi-arid region were alkaline and saline in nature and possessed high CEC but low OC, while humid region soils were acidic, with high OC but low CEC.

Identification of Prime K-bearing Minerals

Semi-quantitative estimation of X-ray diffractograms revealed that feldspar and mica were the only K-bearing minerals identified in sand and silt fractions of these soils (Table 2). These two K-bearing minerals were equally distributed in the sand fraction of semi-arid soils (23-24%) except Palwal. The sand fractions of humid soils showed wide variation in their mica and feldspar content, with values of 10-20 and 15-30%, respectively. The presence of mica (35-45%) in the silt fraction of semi-arid soils was found to be higher than feldspars (18-22%). The content of feldspars in this fraction of humid region soils was almost equal to the semi-arid soils but mica content was remarkably low (10-20%). Illite was the only important K-bearing mineral identified in the finer fraction of the studied soils. Semi-arid soils contained 65-86% illite in their clay fraction while in humid soils it ranged from only 20 to 35%, indicating intense weathering condition of the soils. Kaolinite dominated the clay fractions of humid region soils. The presence of other clay minerals such as vermiculite, smectite and chlorite was low and distribution was almost similar in all the soils except smectite in humid soils.

Potassium Depletion from Soil

Forms of soil K were determined after completion of intensive cropping for 240 days and are pre-

Table 1. Physico-chemical characteristics of soil

Sl. No	Location	Horizon	Taxonomic classification	Particle size distribution (%) Sand	Silt	Clay	Texture	pH	EC (dS m^{-1})	CEC [cmol(p$^+$) kg^{-1}]	OC (g kg^{-1})
1	Palwal	B1	Typic Haplustept	37.8	36.0	26.2	cl	8.8	2.70	11.5	3.9
2	Sonepat	AB	Typic Ustifluvent	80.1	8.7	11.2	sl	10.1	0.30	6.5	1.5
3	Karnal	BA	Typic Natrustalf	51.8	24.5	23.7	scl	9.6	2.53	12.6	3.2
4	Jorhat	Bw1	Oxic Dystrudepts	43.5	27.4	29.1	cl	4.7	0.04	8.2	5.9
5	Kokila	2C1	Typic Fluvaquent	82.5	9.2	8.3	ls	6.8	0.00	6.7	12.5
6	Chatia	BA	Fluventic Dystrudepts	57.6	20.5	21.9	scl	4.5	0.03	7.3	10.1

Table 2. Semi-quantitative estimation of prime K bearing minerals (%) in different particle size fractions

Sl.No.	Location	Sand		Silt		Clay						
		Feldspar	Micas	Feldspar	Micas	I	K	S	V	CH	ISM	O
1	Palwal	23	32	22	45	86	5	2	2	1	-	4
2	Sonepat	24	24	18	38	65	27	4	7	3	-	4
3	Karnal	24	24	18	35	71	12	10	2	2	-	3
4	Jorhat	15	10	20	10	20	70	-	4	2	2	2
5	Kokila	30	15	24	20	35	50	3	6	3	3	3
6	Chatia	19	20	18	17	25	65	-	3	2	2	3

I: Illite, K: Kaolinite, S: Smectite, V: Vermiculite, CH: Chlorite, ISM: Interstratified minerals, O: Others

Table 3. Depletion of potassium from different soil potassium pools after cropping

Sl. No.	Location	Available K (mg kg^{-1})			Non-exchangeable K (mg kg^{-1})			Mineral K (mg kg^{-1})			Total depletion (mg kg^{-1})	Total dry matter yield (g kg^{-1})	Total K uptake (mg kg^{-1})
		BC	AC	DK	BC	AC	DK	BC	AC	DK			
1	Palwal	156 (H)	52 (M)	104	984	484	500	22360	21020	1340	1944	107.2	1580
2	Sonepat	52(M)	24 (L)	28	576	260	316	13872	12548	1324	1668	94.8	1204
3	Karnal	108(M)	36 (L)	72	920	476	444	18372	16904	1468	1984	117.2	1664
4	Jorhat	44 (L)	16 (L)	28	280	176	104	10276	8916	1360	1492	105.6	1124
5	Kokila	72 (M)	16 (L)	56	724	400	324	17304	15422	1882	2262	148	2216
6	Chatia	92 (M)	40 (L)	52	432	300	132	11376	10120	1256	1440	107.2	1164

BC = Before cropping AC = After cropping DK= BC - AC
Letters within the parenthesis indicate available soil K rating.
L = Low; M= Medium; H= High

sented in table 3 along with their original values (Before cropping). The initial rating of the available K went down in all the samples. Palwal exhibited highest depletion (104 mg kg^{-1}) followed by Karnal (72 mg kg^{-}). Potassium depletion from this pool seemed to depend mainly on the initial content as highest depletion was shown by the soils containing larger amount of available K. Similar kind of trend was also noticed in non-exchangeable K as the same two soils showed the maximum depletion of 500 and 444 mg kg^{-1}, respectively. Mineralogical composition played an important role in K release from non-exchangeable pool as depletion was more (48-55%) in semi-arid soils compared to humid soils (31-45%) because of the presence of higher amount of prime K-bearing minerals. The non-exchangeable K contributed 7-13% to the total K depletion in humid region soils while it was 19-26% in semi-arid soils. Significant contribution of non-exchangeable K to crop uptake was also observed by Krishnakumari *et al.* (1984) and Sharma and Verma (2000). Depletion of mineral K was found to be slightly higher 11-13% in humid soils, compared to 6-10% in semi-arid soils. Although humid soils contained lower quantities of prime K-bearing minerals, but continuous and excessive demand of growing plants for soil K might be capable of releasing this nutrient from the structural position of minerals which otherwise is difficult to release.

Irrespective of the textural groups, both mineral and total K depletion was found to be highest in the light textured soil of Kokila, values being 1882 and 2262 mg kg^{-1}, respectively. This soil was composed of fresh alluvium containing appreciable amounts of unweathered /partially weathered micas and weathered alkali feldspar. Sparks (1987) also reported such type of behaviour of a sandy soil consisting high amount of weathered K feldspar. The total K depletion was found to be significantly correlated with total K uptake by plants (r = 0.98**) and total dry matter yield (r = 0.85*). Significant relationship was also observed between total dry matter yield and total K uptake (r = 0.91*).

Depletion of Non-exchangeable Potassium from Particle Size Fractions

The highest depletion of non-exchangeable K (225 mg kg^{-1}) from the sand fraction was recorded in Sonepat soil followed by Kokila (190 mg kg^{-1}) as shown in figure 1a. The clay and silt particles, present in small amounts in sandy soils get exhausted of their reserve K at a faster rate owing to the continuous and excessive crop removal of potassium. This might have caused the release of more resistant reserve K from the sand fraction in these soils. Maximum depletion from silt fraction was recorded in Palwal (Fig.1b). While Karnal and Jorhat soils contained comparable amount of silt particles, depletion was more in the former one because of the presence of large quantities of mica in the silt fraction. The illite dominated clay fraction of semi-arid soils exhibited appreciably higher release of K compared to humid soils (Fig.1c). The lower K release rate from the clay fraction of humid region was also earlier reported by Pal and Durge (1993). The clay fraction exhibited on an average 54.1% depletion of non-exchangeable K followed by sand (43.4%) and silt (38.6%) during the experimental period. These observations are in agreement with the findings of Munn *et al.* (1976) and Mishra and Shrivastava (1994).

Depletion of Mineral Potassium from Different Size Fractions

It has been observed that release of mineral K from all the fractions was comparatively higher in humid soils. Depletion of mineral K from the sand fraction of humid soils was 5.8% compared to 4.1%

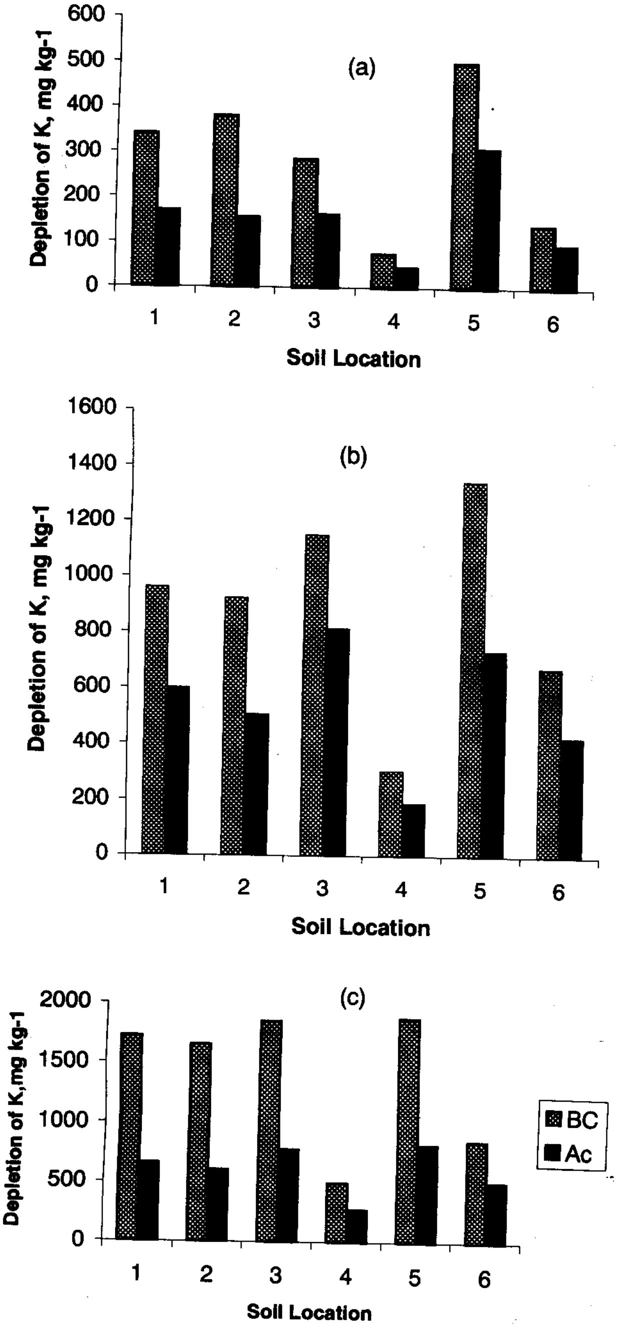

Fig. 1. Depletion of non-exchangeable K from (a) sand, (b) silt and (c) clay
BC: Before cropping AC: After cropping

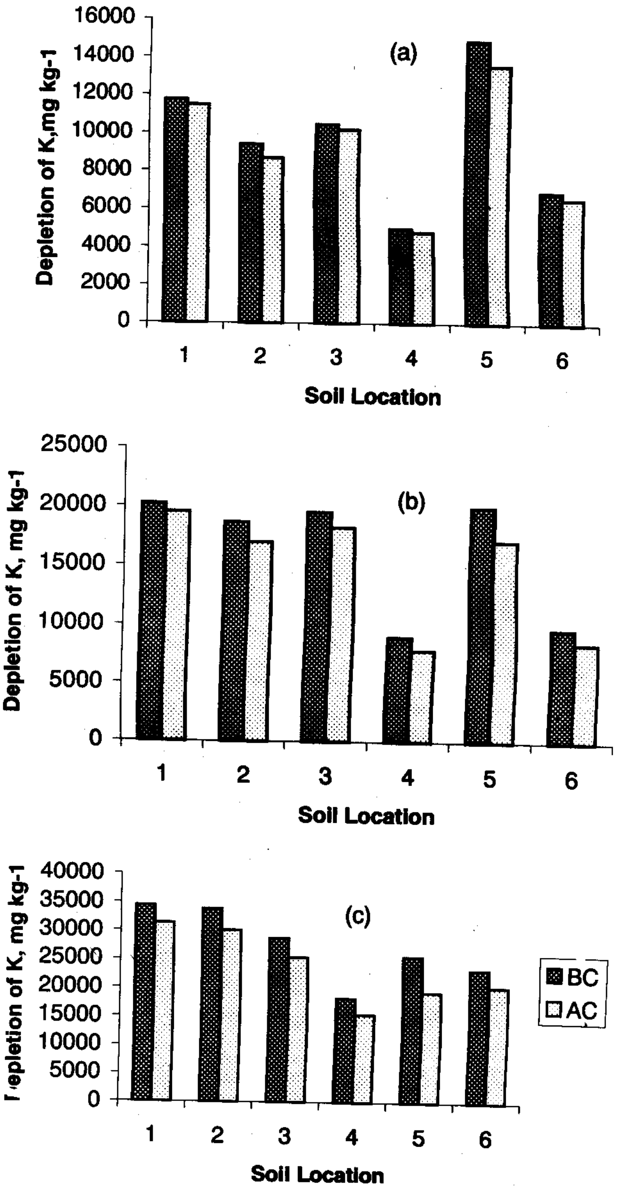

Fig. 2. Depletion of mineral K from (a) sand, (b) silt and (c) clay
BC: Before cropping AC: After cropping

in semi-arid soils (Fig. 2a). Similarly in the silt fraction it was 13.4 and 6.5% and for clay fraction it was 17.8 and 10.5% in humid and semi-arid soils, respectively (Figs. 2b&c). The percentage of mineral K depletion showed an increasing trend with the decrease in particle size which is fully supported by the observation of Datta and Sastry (1993). Maximum depletion of K in all the fractions was recorded in Kokila soils possibly due to its unique mineralogical composition. In this experiment, roots of the plants developed a very dense network within a small area producing a large feeding zone, which may be capable of extracting enough K through root interception in order to meet the K requirement of growing plants. The excessive K requirement might have caused higher release of mineral K from the humid soils, as the release of non-exchangeable K from these soils was quite insufficient to meet the plant demand. Moreover, all these soils have a highly positive and dynamic relationship between non-exchangeable and mineral K (r = 0.97**) and that may help in replenishment of depleted reserve K

The results obtained from the depletion pattern of non-exchangeable and mineral K from the different particle size classes revealed that all these fractions have an important role in supplying K with the demand of growing plants. From the cumulative reduction of K (non-exchangeable and mineral) in sand, silt and clay particles after cropping, it was estimated that the sand fraction of light textured soils contributed more than 50% to the total K depletion. The depletion of potassium obviously resulted from continuous plant removal of K, as there was no other scope of potassium loss from the polyethylene-lined pots. The experiment also showed that one-forth of the total-K depletion was contributed by the silt fractions of medium to medium heavy textured soils. However, more than 60% of the total K depletion, came from the clay fraction in these soils. Mineralogical composition greatly influenced the K supplying power of the individual size groups as soils containing large amount of prime K-bearing minerals exhibited greater release of K during the experimental period.

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