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Comparison of chemical extractants for determination of available potassium

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Abstract

To evaluate different methods for soil potassium availability, surface soil samples (0-15 cm) were collected from 55 locations in Haryana covering a wider range of dominant textures and management conditions. Each soil sample was then equilibrated with 0, 100, 200 and 400 mg K kg^{-1} soil for about a week to obtain soils with a wider spectrum of their initial K content. Available potassium in all the samples air-dried at room temperature was determined using 1N ammonium acetate (NH_4OAc), Mehlich-3 (M3) and sodium tetraphenylboron ($NaBPh_4$). The results showed that the average percent increase in available K extracted by ammonium acetate, Mehlich-3 and sodium tetraphenyl boron for 100, 200 and 400 ppm treated soils was 34.65%, 31.68%, 26.73%; 57.28%, 60.56%, 53.52% and 22.66%, 23.46% and 26.81%, respectively in comparison to 0 ppm treated soils. However, higher (2-3 times) available potassium was extracted by using sodium tetraphenyl boron in comparison to ammonium acetate and Mehlich-3 extractants. The regression model showed best fit for sodium tetraphenyl boron.

Keywords: ammonium acetate, Mehlich-3, potassium, regression, sodium tetraphenylboron

Introduction

The role of potassium (K) in plant growth and soil fertility is extensively documented and is closely associated to the long-term sustainability of the soil, the medium for plant growth (Oborn *et al*., 2005; Romheld and Kirkby, 2010; Zorb *et al*., 2014; Kulcheski *et al*., 2015; Li *et al*., 2016) [17, 18, 24, 12, 13]. Soil testing is an important diagnostic tool to assess the availability of plant nutrients. The extraction of soil with neutral 1 N ammonium acetate (NH_4OAc) from air-dried or oven-dried soil samples is the most widely used soil test for determination of available K. It has been stated that a soil should be tested without disturbing or altering it chemically or mechanically in the process of sample preparation (Gelderman and Mallarino, 1998) [10]. However, testing *in situ* is not technically feasible yet, and soil samples are usually dried and crushed to simplify sample handling and provide a homogenous mix for sub sampling. It has, however, been recognized that drying soil samples can influence the amount of K extracted with the NH_4OAc extractant (Barbagelata, 2006) [3]. McLean and Watson (1985) [14] stated that, if the soil is relatively low in exchangeable K, soil sample drying causes scrolling of layers of the micaceous clay which releases non-exchangeable K. However, if the soil is relatively high in exchangeable K or K is added to it recently, drying usually drives water out from between the layers, causing them to collapse and trap K in non-exchangeable form. Depending on the relative magnitude of these two mechanisms, a net release, fixation, or no change in exchangeable K could be observed.

Further, amongst the extractants, adoption of Mehlich-3 (M-3) test (Mehlich, 1984) [15] is gaining popularity *in lieu* of the traditional NH_4OAc (Haby *et al*., 1990; Allen *et al*., 1994) [11, 1]. The main reason is that M-3 allows simultaneous extraction and determination of several elements in one extraction. Also, evidences indicate that the measurement of exchangeable K may not be the most reliable index of plant-available K for many soils (Bertsch and Thomas, 1985) [5], particularly in those soils that contain substantial amounts of K fixing phyllosilicate clay minerals. Cox and Joern (1996) [8] showed that the NH_4OAc method predicted plant-available K poorly in soils where non-exchangeable K contributed significantly to K nutrition. Therefore, an ideal soil-test for K should quantify the proportion of non-exchangeable K that may potentially become available to plants during the growing season.

The sodium tetraphenylboron (NaBPh4) K extraction method, developed by Scott *et al*. (1960) [20], has received attention as a potential method to estimate plant-available K due to its ability to extract exchangeable K and also part of the non-exchangeable forms of K in soils.

Extraction of K by NaBPh4 is a less drastic treatment of the mineral structures than extraction with boiling 1M HNO_3, which is the classic method used to measure non-exchangeable K in soils (McLean and Watson, 1985) [14]. Moreover, Scott and Reed (1960) [20] demonstrated that the NaBPh4 is an effective extractant for non-exchangeable K from mica structures. The BPh_4^- anion facilitates the release of non-exchangeable K by combining with K in solution and precipitating it as $KBPh_4$, while Na exchanges with interlayer K (Scott and Reed, 1962) [21]. As a result, this method mimics the action of K uptake by plant roots by depleting soil solution K and promoting further release of exchangeable and non-exchangeable K. The plants have a distinct tendency to take up K from soils. Thus, the ability of K extractants to prognosticate plant available K in wide range of soils is imperative. Hence, the study was undertaken to compare the extraction of K by different extractants.

Materials and Methods

The study area, lying in north-west of India, is the part of the Indo-Gangetic Plains. The state of Haryana is one of the most agriculturally productive areas of India and is of broad agro-ecological significance. Surface soil samples (0-15 cm depth) were collected from 55 locations across the state following standard techniques. The post hole auger was used for collecting the soil samples. The sampling locations are depicted in figure 1. The samples represented a wider range of soil types (dominant textures) and management conditions. The fields were selected randomly where the farmers are using different management practices. The soil samples were air-dried, thoroughly ground and passed through 2 mm sieve, subsequently, were stored in the plastic containers and used for analysis of different forms of potassium. The study involved measurement of potassium using three extractants viz., ammonium acetate, Mehlich-3 and sodium tetraphenylboron form soils air-dried at room temperature. To obtain soils with a wider spectrum of their initial K content, each soil sample was equilibrated with 0, 100, 200 and 400 mg K kg^{-1} soil for about a week. Potassium was then extracted using 1*N* NH_4OAc, Mehlich-3 (M-3) and sodium tetraphenylboron ($NaBPh_4$) at air drying temperature. Potassium was determined using flame photometer and the results were compared for different extractants. A screen house experiment was carried on bulk surface samples collected from Hisar, Hansi, Barwala, Sirsa and Shahpur widely varying in their texture and/or initial K status using maize as the test crop. After processing, these soils were filled in earthen pots of 5 kg capacity each. Potassium were applied @ 0, 50, 100 and 150 mg K kg^{-1} in each soil and allowed to equilibrate with the soil for one week with intermittent watering and mixing of soil. Soil samples were collected from each pot before sowing of the crop. Potassium was analyzed using different extractants. Maize HM-11 was sown in each pot keeping 8-10 viable seeds and after germination 4 plants were maintained in each pot. The crop were raised till grand growth stage, harvested, weighed and analyzed for K and K uptake was calculated. The K uptake by maize was correlated with potassium content extracted by using different methods and extractants to find out the effectiveness of these tests and methods.

Results and Discussion

The data of potassium extracted using ammonium acetate, Mehlich-3 and sodium tetraphenylboron from air-dry soil samples are presented in table 1. The pattern of K extraction at higher concentration of 100, 200 and 400 ppm K treatments increased correspondingly. The results showed that concentration of potassium extracted with tetraphenyl boron method varied widely with other two methods since each extractant desorbed different portions of potassium. The average percent increase in available K extracted by ammonium acetate, Mehlich-3 and sodium tetraphenyl boron for 100, 200 and 400 ppm treated soils was 34.65%, 31.68%, 26.73% ; 57.28%, 60.56%, 53.52% and 22.66%, 23.46% and 26.81% in comparison to 0 ppm treated soils. However, higher available potassium was extracted by using sodium tetraphenyl boron in comparison to ammonium acetate, Mehlich-3 extractants (Table 1). It is quite clear from the graph that both ammonium acetate and Mehlich-3extractants extracted almost similar amounts of soil K in all the samples irrespective of type and initial potassium status of soil. The strong coefficient of determination (R^2=0.99) indicates that the extraction behaviour of both these extractants is almost same (Figure 2). This may be because of the fact that M-3 also contains salts of ammonium acetate as one of its component. The magnitude of K extracted by both extractants increased relatively proportionally, with increase in quantity of superimposed K in soils. The same trends were observed in the magnitude of K by the two methods when air drying methods of K extraction were followed. Sodium tetraphenyl boron ($NaTBh_4$) extracted 2-3 times higher K than NH_4OAc or Mehlich-3 extractants in all the soils. These differences were observed even with increasing concentrations. Comparable relationships between these two tests have also been reported by others (Michaelson *et al*., 1987; Gartley *et al*., 2002; Wang *et al*., 2004) [16, 9, 23]. Beegle and Oravec (1990) [4] working with field calibration studies conducted at 67 sites in Pennsylvania, reported a significant relationship between NH_4OAc and M3 extractable K. Charles *et al*. (1989) [6] reported that the amount of K extracted by M-3 was nearly same as extracted by ammonium acetate (R^2 =0.92). Chilimba *et al*. (1999) [7] investigated the use of a universal soil extractant (M-3) and the objectives of the study were to compare the universal soil extractants (M3) and modified Olsen (MO) extractant with ammonium acetate (AA). They observed that Mehlich-3 extracted 12% more K than AA. These results are similar to the finding of Mehlich (1984) [15] who reported that M-3 extracted 6-8% higher K than AA. The correlation between M-3 and AA was highly significant (r = 0.90).

Cox *et al*. (1996 and 1999) [8] also reported that $NaBPh_4$ test may provide reliable estimates of K supply for a wide range of soil types and environmental conditions because it is less sensitive to sample drying. $NaBPh_4$ method extracted six to ten times more K than the other method used. Wang *et al*. (2010) [22], however, observed that the $NaBPh_4$ method is largely dependent on the components of the extractant and the extraction period. Similar finding by Schindler *et al*. (2002) [19], while working with six soils from east-central South Dakota, found a higher correlation (r = 0.95) between K measured by NH_4OAc and $NaBPh_4$ (5-min incubation). The differences in magnitude were more pronounced at lower K status or concentrations. When exchangeable K is depleted to its critical level (low K saturation in the exchange complex or high Ca and Mg to K ratio), and there is a low concentration of K ions in solution (due to crop removal, for example), K release from non-exchangeable pools is favoured to allow further K uptake, which would reduce the amount of non-exchangeable K potentially extractable by $NaBPh_4$ (McLean and Watson, 1985) [14]. The relationship of K extraction behaviour between Mehlich-3 and $NaBPh_4$ was almost similar as recorded for NH_4OAc and $NaBPh_4$.

Furthermore, linear regression models were fitted to the data as shown in table 2. The results indicated that the coefficient of determination ($R^2 = 0.819$) was higher for $NaBPh_4$ thereby indicating that the regression equation was the best fit for this extractant. Aramrak *et al.* (2007) [2] ascertained that the amounts of K extracted by Mehlich-3 and AB-DTPA were highly regressed with those extracted by NH_4OAc.

The data on K uptake by maize crop are presented in table 3. A strongest correlation of potassium uptake by maize was observed with K extracted using $NATBh_4$ (Table 3), suggesting that the K extracted using this method is more closely related to K uptake by plants in these soils and hence could be used as a better index of potassium availability. However, this method is more cumbersome in its extraction procedure and also the cost of $NaTBh_4$ is relatively too high than NH_4OAc and Mehlich-3. The sodium tetraphenylboron ($NaBPh_4$) K extraction method, determines exchangeable as well as a part of the non-exchangeable forms of K in soils (Scott *et al.*, 1960) [20]. Scott and Reed (1960) [20] in early studies demonstrated that the NaBPh4 is an effective extractant for non-exchangeable K from mica structures. The BPh_4- anion facilitates the release of non-exchangeable K by combining with K in solution and precipitating it as KBPh4, while Na exchanges with interlayer K. As a result, this method mimics the action of K uptake by plant roots by depleting soil solution K and promoting further release of exchangeable and non-exchangeable K. Wang *et al.* (2010) [22] also reported that NH_4OAc-extractable K (NH_4OAc-AK) and $NaBPh_4$ 60-min-extractable K ($NaBPh_4$-AK) showed good linear correlation to ryegrass leaf K concentration or uptake.

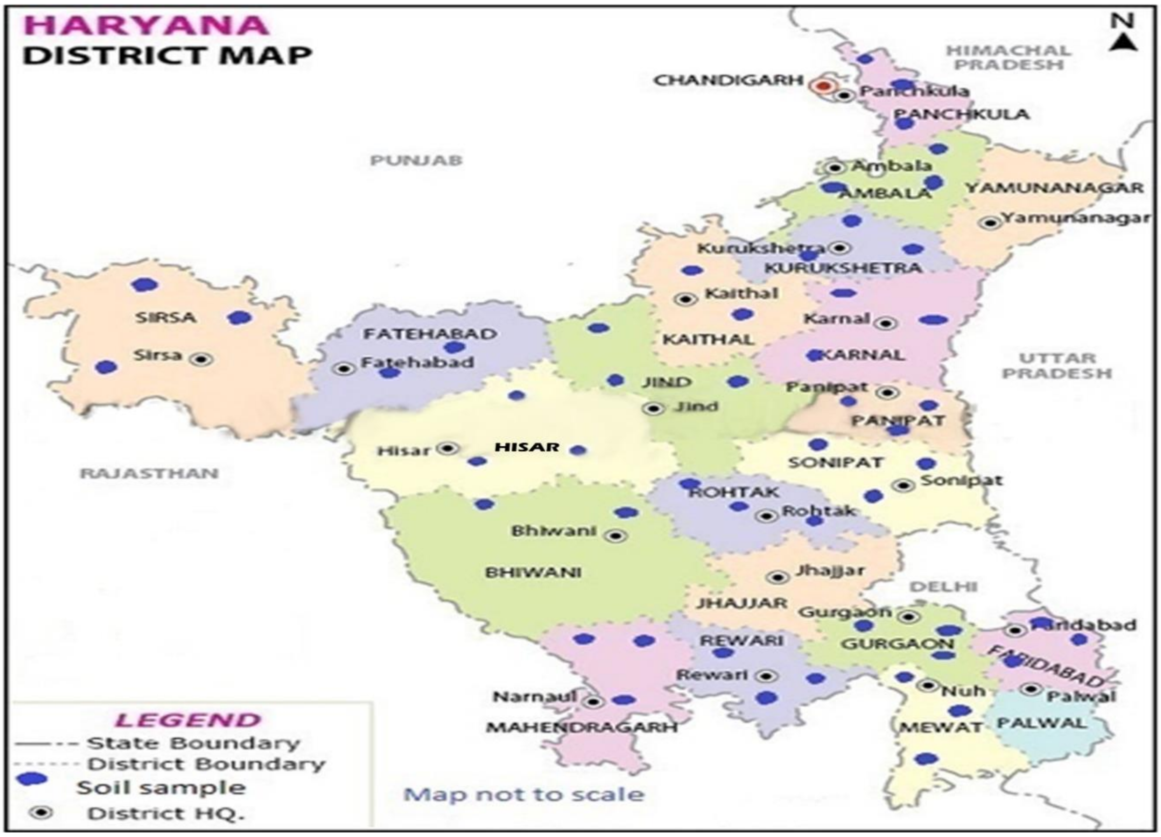
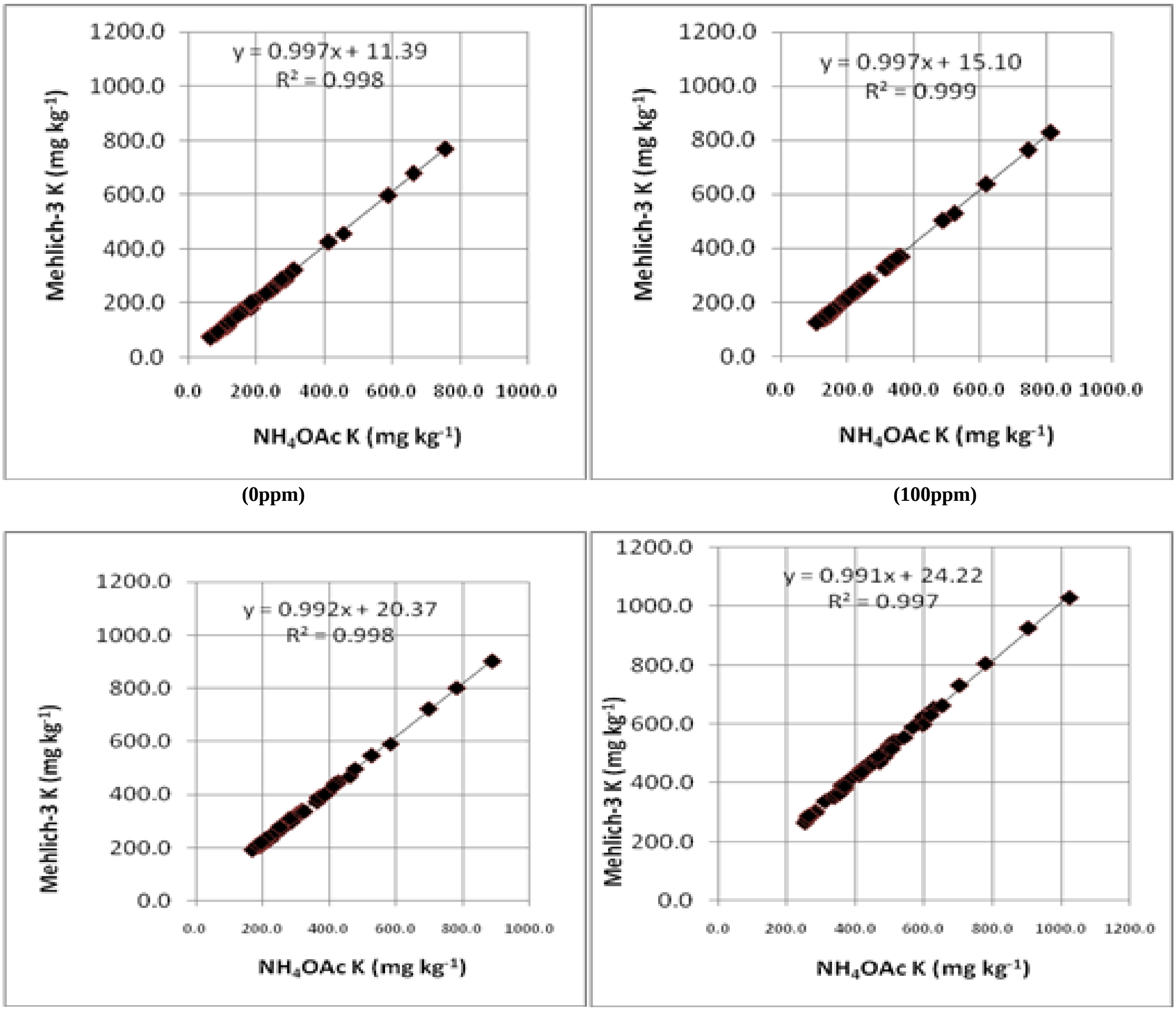


Fig 1: Soil sampling locations on Haryana map

Table 1: Range and mean of K (mg kg^{-1}) as extracted by different extractants in K treated air-dry soil samples

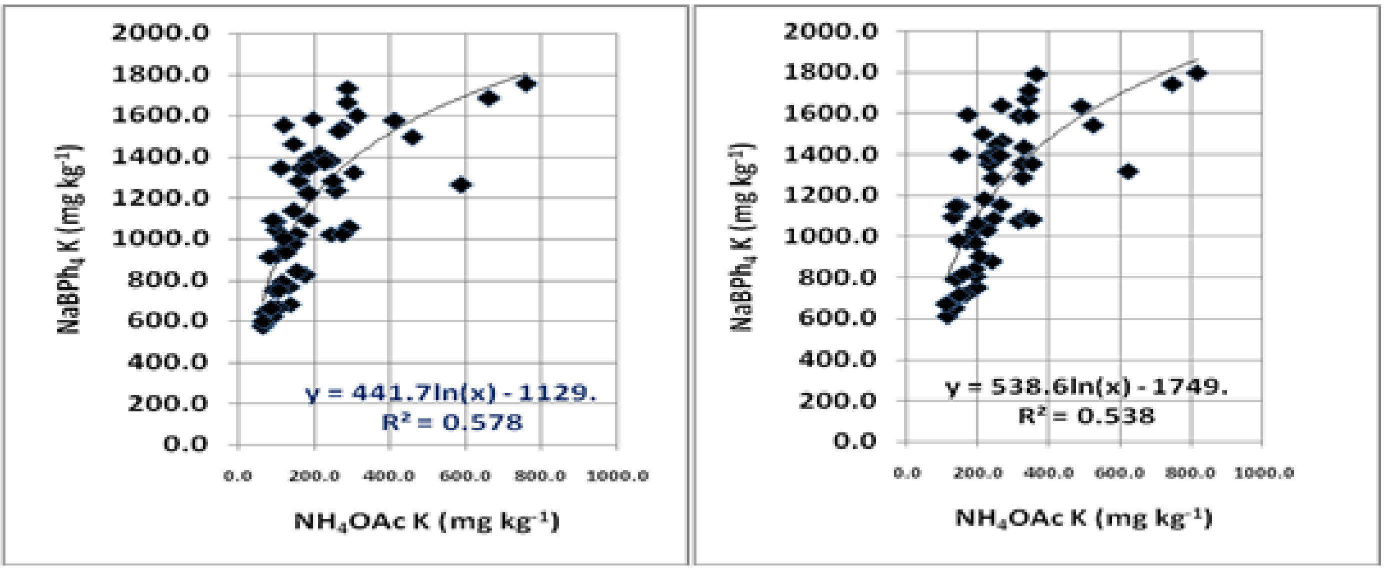
Treatment	Methods for estimation	Range	Average
0 ppm K	NH_4OAc	62-758	202
	Mehlich-3	73-768	213
	$NaBPh_4$	573-1753	1134
100 ppm K	NH_4OAc	109-817	272
	Mehlich-3	127-829	277
	$NaBPh_4$	713-1797	1188
200 ppm K	NH_4OAc	168-890	324
	Mehlich-3	192-902	342
	$NaBPh_4$	678-1861	1248
400 ppm K	NH_4OAc	254-1023	459
	Mehlich-3	266-1028	479
	$NaBPh_4$	903-2055	1438



(0ppm) (100ppm)

(200ppm) (400ppm)

Fig 2: Relationship between Ammonium-acetate (NH_4OAc) and Mehlich-3 (M3) K extractable methods in air dry soil samples



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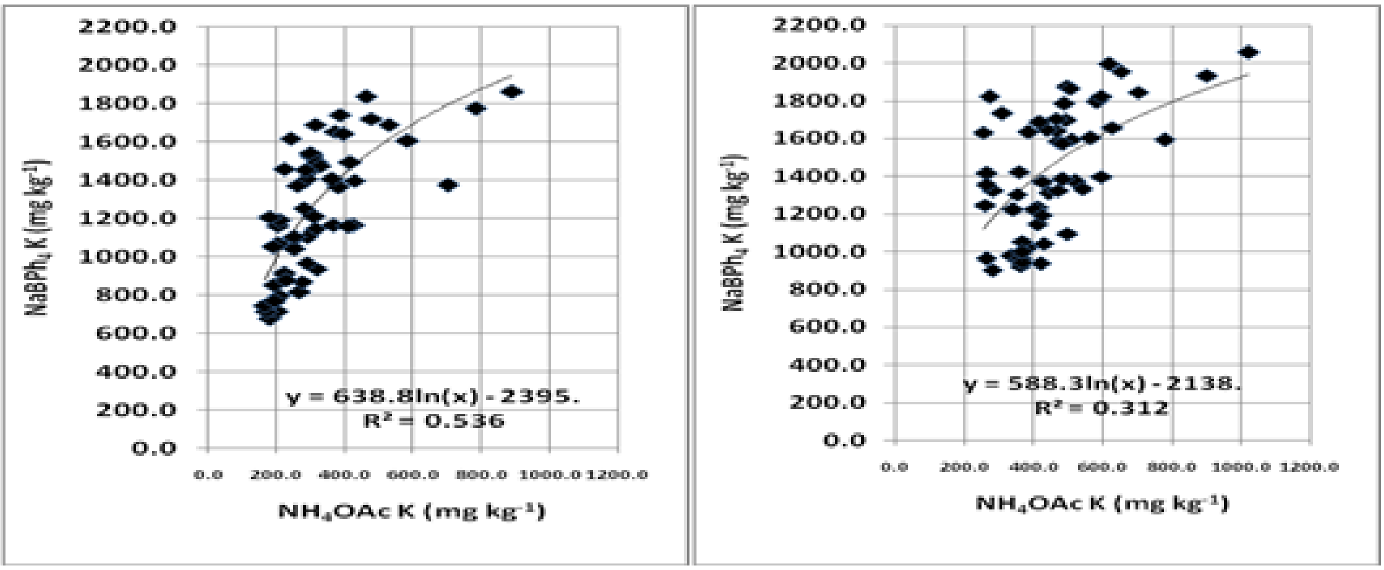
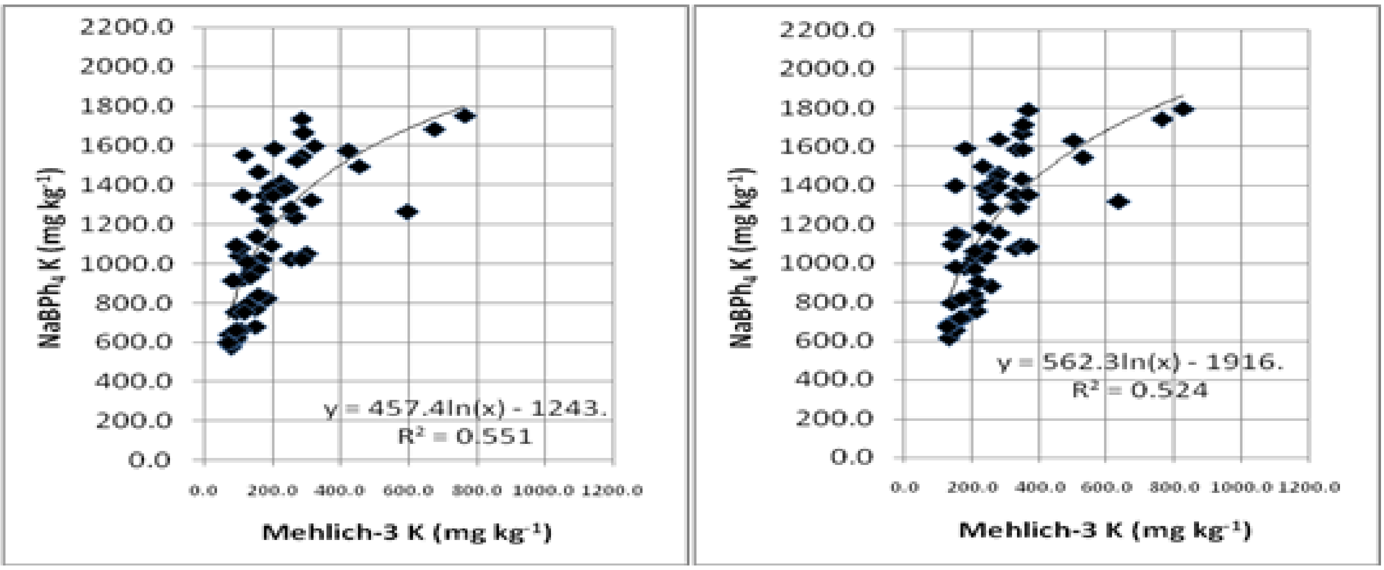
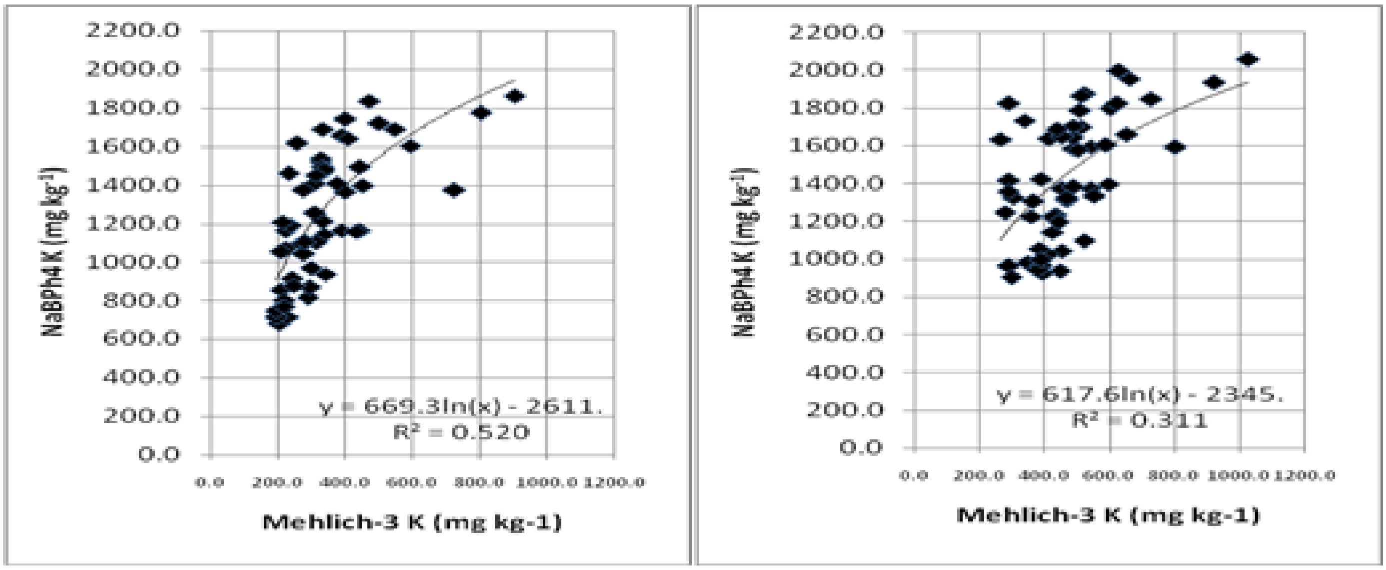


(200ppm) **(400ppm)**

Fig 3: Relationship between ammonium acetate (NH4OAc) and sodium tetraphenylboron (NaBPh4) K extractable methods in air dry soil samples



(0ppm) **(100ppm)**



(200ppm) **(400ppm)**

Fig 4: Relationship between Mehlich-3 and Sodium tetraphenylboron K extractable methods in air dry soil samples

Table 2: Regression equations and coefficient of determination (R^2) for relationships between amounts of K extracted by ammonium acetate, Mehlich 3 and sodium tetraphenyl boron extractants (all values are significant at $p \leq 0.01$)

Extract	Regression Equations	Coefficient of determination (R^2)
NH_4OAc	y = 0.644x + 541.6	0.689
M-3	y= 0.656x + 527.7	0.699
$NaBPh_4$	y = 0.487x + 250	0.819

Table 3: Potassium uptake by maize crop under different soil treatments

Soil Samples	Treatments (K ppm)	K Uptake (mg/pot)
Barwala	0	663
	50	698
	100	730
	150	762
Hau	0	600
	50	650
	100	713
	150	719
Hansi	0	563
	50	589
	100	654
	150	682
Shahpur	0	580
	50	618
	100	636
	150	663
Sirsa	0	736
	50	756
	100	809
	150	864

Conclusion

Based on the results of the study it is concluded that both 1N ammonium acetate (NH_4OAc) and Mehlich-3, extracted almost similar amounts of soil potassium irrespective of the type and initial K status of the soil. The correlation coefficient between the K extracted by these two methods ranged from 0.98 to 0.99, indicating strong significant similar extraction behaviour of the two methods. Sodium tetraphenylboron ($NaTBh_4$) extracted 2-3 times higher K than NH_4OAc or Mehlich-3 extractants in all the soils. Hence, $NaTBh_4$ is the best extractant for determination of available potassium.

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