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# Response of wheat to potassium and its fractions in Punjab soils

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ABSTRACT

A pot experiment was conducted at screen house of Department of Soil Science, PAU, Ludhiana during *rabi* 2017-18 to evaluate the response of wheat to applied potassium. Twelve soil samples were taken from all over Punjab varying in available K. Potassium was applied @ 0, 15, 20, 25 and 30 kg K/ha soil. The mean grain yield varied from 12.39 to 20.13 g/pot in K sufficient soils (>137 kg K/ha) and 8.43 to 12.09 g/pot in K deficient soils (<137 kg K/ha). Increase in grain yield was significant up to 25 kg K/ha in K sufficient soils, however in K deficient soils, wheat responded up to 30 kg K/ha. Application of 30 kg K/ha resulted in significant increase in content of K fractions (water soluble K (WSK), exchangeable K (EXK) and non exchangeable K (NEK) as compared to control in both K sufficient and deficient soils. WSK showed significant and positive correlation with EXK (0.964*) and NEK (0.872*) indicating dynamic equilibrium between these forms of K. About 70.5 and 93.4% variation in grain yield of wheat was due to the combined influence of WSK and EXK in K sufficient and deficient soils, respectively. NEK accounted for only 0.9 and 5.2% variation in grain yield in K sufficient and deficient soils, respectively. Hence, contribution of NEK towards wheat yield in K deficient soils was higher as compared to K sufficient soils. Therefore, K deficient soils are more responsive to potassium application as compared to K sufficient soils**.**

**Keywords**: Potassium fertilization, Potassium uptake, Soil K fractions, Wheat, Yield

Potassium (K), an essential plant macronutrient, constitutes approximately 1.9% of the earth's crust (Tisdale *et al.* 1985). The application of K in wheat has a vital role in photosynthesis, synthesis of carbohydrates, proteins, and causes resistance against pest and diseases (Kubar *et al.* 2018). In K deficient soils, K fertilization is required for supplementing the native K supplying capacity of soil to meet the K requirement of crops. There are different forms of K present in soils like exchangeable, water soluble, nonexchangeable and structural forms which exist in dynamic equilibrium (Sujatha *et al.* 2017). Water soluble and exchangeable fractions of K are easily taken up by the plants. Thus, these forms constitute the readily available pools of K (Lalitha and Dhakshinamoorthy 2014). The contribution of non exchangeableK to total uptake becomes significant in soils deficient in exchangeable K (Sharpley 1989).

In India, different soil test laboratories recommend K fertilizer based on available (exchangeable+ water soluble) pools of K present in soils. However, recent studies showed a significant contribution of the non exchangeable fraction of K to crop K uptake because of its more abundance in soil than exchangeable and solution K (Wang *et al.* 2016). Therefore, the availability of native K to plants is often predicted better by including the contribution from non exchangeable K. Analysis of a large number of samples by soil testing laboratories in the state of Punjab also showed a wide variation in the available K in the soils of the region. Therefore, the present study was undertaken to assess the response of wheat to applied K in soils ranged in available K and to investigate the effect of K fertilization on different fractions of K and contribution of these forms of K to wheat.

## MATERIALS AND METHODS

*Collection of soil samples*: Pot experiment was conducted at screen house of Department of Soil Science, Punjab Agricultural University, Ludhiana, Punjab, India during *rabi* 2017-18 to study the response of wheat crop to K application.Twelve bulk soil samples (0-15cm) representing different parts of Punjab were collected. These samples were tested for available K and various physical chemical characteristics of soils. Out of the tested twelve samples, eight soil samples from Mansa, Sangrur, Faridkot, Amritsar, Patiala, Tarantaran, Kailpur and Ludhiana were sufficient in available K (>137 kg K/ha) with 521, 422, 468, 353, 386, 153, 235 and 149 kg K/ha, respectively, representing south west and central alluvial plain of Punjab and four samples from Nawashehar, Garhshankar, Bahowal and Gurdaspur were deficient in available K (<137 kg K/ha) with 125, 131, 121 and 113 kg K/ha, respectively representing north eastern

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plain. The soil *p*H (1:2 soil:water suspension), electrical conductivity (EC), soil organic carbon (SOC) (Walkleys and Black 1934), available nitrogen (N) (Subbiah And Asija 1956), available P (Olsen *et al*. 1954) and available K (Ammonium acetate method at *p*H 7) was determined.

*Preparation of soil samples and treatment details:* The collected soil samples were air dried, ground with a pestle mortar and sieved through 2 mm sieve. The polyethylene lined plastic pots with 10 kg capacity were filled with 8 kg of sampled soil. The K was applied @ 0, 15, 20, 25 and 30 kg K/ha soil through muriate of potash (60% $K_2O$). The treatments were replicated thrice and randomised in a Factorial Complete Randomized Design. The basal dose of N and P was applied by 50 kg N/ha soil and 25 kg $P_2O_5$ $ha^{-1}$ soil through analytical reagent (AR) grade urea and monocalcium phosphate, respectively. Wheat (cv PBW 725) was sown on 10$^{th}$ Nov, 2017 with ten seeds per pot and harvested at maturity on 15$^{th}$ April, 2018. After germination, crop was thinned to five plants per pot.

*Collection of soil samples and analysis:* After the harvest of crop, soil samples were collected from each pot with the help of a stainless steel tube auger, air dried, ground and analysed for K fractions. Different fractions of K like water soluble K (Jackson 1965), exchangeable K (Pratt 1982), non exchangeable K (after subtracting available K from nitric acid extractable K) were determined. The K from the extracts was measured on flame-photometer.

*Collection of plant samples and analysis*: After the harvest of crop at maturity, the grain and straw samples were collected manually from each pot and straw samples were washed thoroughly in succession with tap water, 0.1N hydrochloric acid (HCl) and deionised water and oven dried at 60$^o$C to constant weight. Then these samples were stored for chemical analysis after ground with an electric grinder. Half gram of oven dried grain and straw samples were wet digested in di-acid mixture of $HNO_3$ and $HClO_4$ (3: 1) and total K in the extract was determined with the help of flame photometer (Jackson 1965). Relative wheat grain and straw yield was calculated as:

$$\text{Relative yield (\%)} = \frac{Y_0}{Y_1} \times 100$$

where $Y_0$ is the yield of untreated pot and $Y_t$ is the yield of treated pot.

*Statistical analysis*: The statistical analyses were performed using analysis of variance (ANOVA) for factorial complete randomized design and data were analysed using SPSS software. The data were also subjected to linear correlation and stepwise regression to establish the relationship between soil K fractions and crop yield, K uptake and K concentration.

## RESULTS AND DISCUSSION

*Grain yield of wheat*: The grain yield of wheat at different locations with the application of different levels of K ranged from 18.11 to 20.13, 12.39 to 17.87 and

Table 1 Effect of potassium application on the grain yield of wheat (g/pot) in potassium sufficient and deficient soils

| Soil | Levels of K applied (kg K/ha soil) | | | | | | Relative grain yield (%) |
|---|---|---|---|---|---|---|---|
| | 0 | 15 | 20 | 25 | 30 | Mean | |
| *Potassium sufficient soils (> 137 kg K/ha)* | | | | | | | |
| *South western Plain* | | | | | | | |
| Mansa | 17.86 | 20.33 | 21.10 | 21.73 | 19.63 | 20.13 | 82.2 |
| Sangrur | 17.83 | 19.20 | 19.86 | 20.50 | 18.80 | 19.24 | 87.5 |
| Faridkot | 17.12 | 18.23 | 18.43 | 18.81 | 17.86 | 18.11 | 90.4 |
| *Central alluvial plain* | | | | | | | |
| Amritsar | 16.52 | 17.81 | 18.53 | 19.05 | 17.46 | 17.87 | 87.1 |
| Patiala | 11.50 | 12.86 | 14.13 | 14.76 | 13.78 | 13.41 | 77.9 |
| Tarantaran | 12.20 | 13.63 | 14.92 | 15.53 | 13.90 | 14.03 | 78.6 |
| Kailpur | 10.83 | 11.83 | 12.90 | 13.52 | 12.89 | 12.39 | 79.9 |
| Ludhiana | 10.63 | 12.26 | 13.83 | 14.86 | 14.30 | 13.26 | 69.2 |
| Mean | 14.31 | 15.76 | 16.71 | 17.33 | 16.07 | | |
| CD (5%) | Soils = 0.63 | | K levels = 0.49 | | Soil × K levels = 1.3 | | |
| *Potassium deficient soils (< 137 kg K/ha)* | | | | | | | |
| *North Eastern Plain* | | | | | | | |
| Nawashehar | 7.23 | 9.43 | 11.23 | 12.36 | 13.86 | 10.82 | 51.7 |
| Garhshankar | 8.30 | 10.46 | 12.66 | 13.86 | 15.16 | 12.09 | 54.6 |
| Bahowal | 5.08 | 8.23 | 8.56 | 11.28 | 13.03 | 8.75 | 45.3 |
| Gurdaspur | 4.13 | 7.48 | 9.30 | 10.35 | 11.92 | 8.43 | 38.1 |
| Mean | 6.18 | 8.90 | 10.43 | 11.96 | 13.49 | | |
| CD (5%) | Soils = 0.79 | | K levels = 0.88 | | Soil × K levels = 1.1 | | |

8.43 to 10.82 in south western, central alluvial and north eastern plain, respectively and the corresponding relative yield varied from 82.4 to 90.4, 71.5 to 86.7 and 34.6 to 54.7% (Table 1). The significant and positive response of wheat was obtained up to 25 kg K/ha application only in K sufficient soils.Whereas, in the K deficient soils (< 137 kg K/ha) of the north eastern plain of Punjab, the mean grain yield increased significantly up to the highest level of applied K (30 kg K/ha).The wheat grain yield showed higher response to K application in all the K deficient soils as compared to K sufficient soils because of limiting factor in K deficient soils. The highest response was recorded in soil from Gurdaspur (lowest relative grain yield=34.6%) with 188 % increase in yield over control with 30 kg K/ha.The lowest response was recorded in soil from Faridkot (highest relative grain yield=90.4%) showing only 10.6% increase in yield over control with 25 kg K/ha applied K. Decline in available K status due to heavy rainfall in northeast plain of Punjab might be the reason for large response of crop in this plain. The higher response to applied K observed in northwestern districts of Punjab as compared to southwestern districts could be attributed to lower rates of K release from clay minerals in the former region (Hundal and Pasricha 1993). Azad *et al*. (1993) observed that wheat yield increased significantly up to 75 kg K/ha on soils testing low in available K, whereas on soils testing medium as well as high in available K, significant response of wheat yield was observed only up to 25 kg K/ha. During field experimentation, Singh and Bhandari (1995) also reported larger response of rice to applied K in north eastern districts (Amritsar, Hoshiarpur, Kapurthala and Gurdaspur) as compared to central and south west districts (Bathinda, Ludhiana, Sangrur, Ferozepur) of Punjab.

*Fractions of K*: All the forms of K increased with the increase in the rate of applied K in both K sufficient and K deficient soils. Water soluble K was the least dominant form and its mean value varied from 19.4 to 23.2, 11.8 to 17.7 and 8.86 to 11.4 mg/kg soil in soils of south western, central alluvial and north eastern plain, respectively (Fig 1(a)). The increase in water soluble K with the addition of graded levels of K was higher in K deficient soils compared with K sufficient soils. Increase in water soluble K might be attributed to increase in concentration of K in solution due to incremental levels of K application. The higher content of all the forms of K was noted in K sufficient soils as compared to K deficient soils. Elbaalawy *et al.* (2016) also reported that the higher content of water soluble K in the south-western alluvial plain zone may be attributed to high salt accumulation in this region as indicated by relatively higher electrical conductivity.

The mean exchangeable K varied from 213.1 to 379.8, 125.2 to 193.9, 66.1 to 73.4 mg/kg soil in soils of south western, central alluvial and north eastern plain, respectively (Fig 1(b)). The increasing levels of K application might have been responsible for the higher content of exchangeable K at highest level of applied K. Jadhao *et al.* (2015) reported that various K fertilizer treatments significantly increased exchangeable K. The content of mean non exchangeable K ranged from 1503.8 to 1631.7 and 898.4 to 1369.6 mg/kg soil in soils of south western, central alluvial and north eastern plain, respectively. The increase in non exchangeable K with the increasing levels of K application indicated that increasing levels of K were also beneficial in improving non exchangeable K pool of soil. Talashikar *et al.* (2006) also reported that various potassic fertiliser treatments significantly increased non exchangeable K.

*Coefficients of correlation among various K fractions and relationship of K fractions with wheat yield and K uptake*: All the forms of K were positively and significantly correlated with each other. The non exchangeable K had positive relationship with all other K fraction indicating that there exists equilibrium between different forms of K and a depletion of one form is replenished by the other forms. The non exchangeable K was positively and significantly correlated with water soluble K (0.872*) and available K (0.806*). The exchangeable K was positively

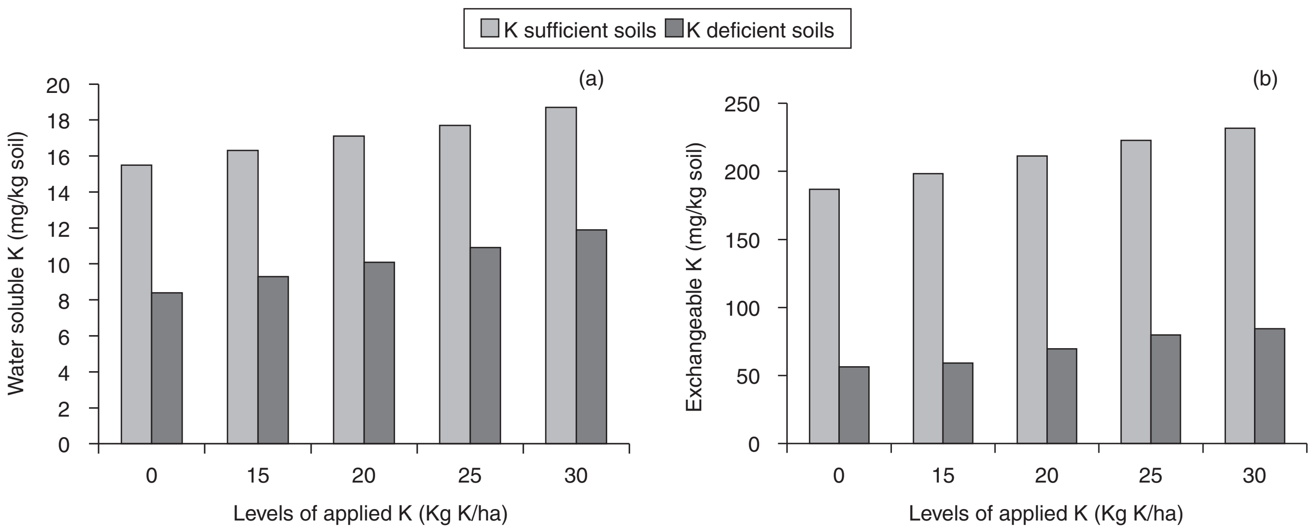


Fig 1 Effect of potassium application on water soluble K (a) and exchangeable K, (b) in potassium sufficient and deficient soils.

Table 2 Stepwise regression analysis relating the different forms of potassium to various plant parameters in potassium sufficient and K deficient soils

| Plant parameter | Intercept | WSK | EXK | NEK | $R^2$ |
|---|---|---|---|---|---|
| *K sufficient soils* | | | | | |
| Grain yield (g/pot) | 3.38 | 4.47 | | | 0.698* |
| | 3.23 | 0.86 | -0.008 | | 0.705* |
| | -6.38 | 2.72 | 2.17 | 0.096 | 0.714* |
| K uptake (mg/pot) | -3.38 | 4.01 | | | 0.558* |
| | -9.12 | 4.86 | -0.04 | | 0.561* |
| | -105.8 | 32.53 | 30.95 | 0.09 | 0.572* |
| *K deficient soils* | | | | | |
| Grain yield (g/pot) | -3.96 | 1.40 | | | 0.904* |
| | -6.06 | 1.01 | 0.085 | | 0.934* |
| | -20.62 | 40.28 | 40.29 | 0.008 | 0.986* |
| K uptake (mg/pot) | -19.35 | 4.28 | | | 0.734* |
| | -40.59 | 0.29 | 0.86 | | 0.777* |
| | -25.76 | -50.21 | -50.77 | -0.005 | 0.787* |

*Significant at 5%. WSK= Water soluble potassium, EXK = Exchangeable potassium, NEK = non exchangeable potassium

and significantly correlated with water soluble K (0.964*), available K (0.948*) and non exchangeable K (0.801*). The higher degree of positive and significant correlation was recorded between exchangeable K and water soluble K (r=0.964*). Rajeevana and Kavitha (2018) also concluded that different K fractions were positively and significantly correlated with each other indicating dynamic equilibrium among various fractions of K. The data revealed that the grain yield of wheat was positively and significantly correlated with water soluble (0.905*), exchangeable K (0.831*) and non exchangeable K (0.815*). The water soluble K had the highest positive and significant correlation with wheat grain yield (0.905*) and K uptake (0.887*) indicating that easily available form of K has significant impact on grain yield and K uptake followed by exchangeable K {0.859*(K uptake)} and non exchangeable K {0.843*(K uptake)}.

*Contribution of different forms of K to wheat nutrition in K deficient and K sufficient soils*: The contribution of different forms of K to the grain yield and total K uptake of wheat through step wise regressions (Table 2) revealed that in K sufficient soils, these fractions contributed about 71.4 % and 57.2 % of the variation in grain yield and K uptake of wheat, respectively. Whereas in K deficient soils, these fractions contributed 98.6 and 57.2% in grain yield and K uptake, respectively. Further, it was found that non exchangeable K accounted for only 0.9% variation in the grain yield of K-sufficient soils, however, in K deficient soils it contributed 5.2% towards the grain yield of wheat. Sharpley (1989) also reported that contribution of non exchangeableK to total uptake becomes significantin soils deficient in exchangeable K (Sharpley 1989).

So results of present investigation clearly demonstrated that wheat crop response to applied K was larger in low available K status soils as compared to medium and high K rated soils. The water soluble and exchangeable were dominant forms of potassium contributing towards wheat yield but non exchangeable K contribution was higher in low K status soils as compared to K sufficient soils.

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