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EFFECT OF POTASSIUM APPLICATION ON PHOSPHORUS USE EFFICIENCY IN MAIZE CROP

Ijaz Ahmed[*1], Saif Ullah Yaqoob[2], Muhammad Naeem[3], Muhammad Haroon[4], Abdul Wakeel[5], Dad Jan[6], Maqbool Ahmed[7], Saraj Ahmed[8], Nazish Ranna[9], Zakia Bibi[10]

*[*1]Agriculture Officer on farm Water Management Kharan, Balochistan, Pakistan.*
[2]Department: on-farm Water Management, Gwader, Balochistan, Pakistan.
[3,4,7]Directorate Agriculture Research Cereal Crops, Agriculture Research Institute Sariab Road Quetta,Balochistan, Pakistan.
[5]Associates Professor University of Faisalabad, Punjab, Pakistan.
[6]Research Officer Directorate of Agriculture Wayaro farm at Uthal Lasbela, Balochistan, Pakistan.
[8]Directorate of Agriculture Research (Dates) Kech at Turbat Balochistan, Pakistan.
[9]Directorate Agriculture Research Institute Sariab Road Quetta, Balochistan, Pakistan.
[10]Directorate of Agriculture Research Fruit Sariab, Quetta, Balochistan, Pakistan

[*1]ijazbaloch963@gmail.com

ABSTRACT
Phosphorus (P) is an essential nutrient needed by plant in large amounts, and play major role in the plant physiological process. P ion is taken up by the plants as HPO_4^{2-} and $H_2PO_4^-$ and is very immobile in soil and less soluble nutrient, due to which less available to crops. P solubility may also be improved by applying K fertilizer as K can improve proton release from plant roots by plasmamembrance H^+-ATPase. The objective of current study was to investigate the effect of potassium on phosphorus use efficiency. A pot experiment was conducted and maize was used as experimental crop. Thirty pots were used with 20 kg soil per pot and there were three K treatments, including control (N), recommended and double of recommended doses of K fertilizer. And P treatments include control and recommended dose of P using different source of P i.e. rock phosphate, single super phosphate and di-ammonium phosphate. Crop was harvested after seven weeks and after harvesting K was determined by using flame photometer and P was determined by spectrophotometer. The data recorded were analyzed using two-way ANOVA and differences among the treatment means were compared using LSD test at 5% significance level. Where K was applied at double recommended dose with recommended rate of nitrogen and phosphorus with DAP source increased shoot length, shoot fresh weight, dry shoot weight, root fresh weight and dry root weight. Furthermore P uptake in root and shoot was also increased due to double rate of potassium along with P (DAP). Application of potassium rate show positive effect on availability of phosphorus, when P was applied as DAP, while for other P source response was not found.
Keywords: *Applications, Potassium, Phosphorus, Efficiency, Maize Crop.*

INTRODUCTION
Phosphorus is an important plant nutrient and its concentration in plants ranges from 0.05 to 0.50% dry weight (Li et al., 2010). A plant needs two nutrients majorly, i.e., phosphorus and potassium, along with nitrogen for normal growth (Mahiwal & Pandey, 2022). The soil has abundant reserves

of phosphorus and potassium nutrients (Delgado et al.2024). It is hard to believe that plants suffer a deficiency of these nutrients in the soil (Younas et al., 2023). The main reason for this suffering is that these nutrients are not present in active form or directly available to the plants in the soil (Brevik et al.2020). The conversion of phosphorus and potassium nutrients into available form by using fertilizer requires a higher than threshold amount of these nutrients in the soil to achieve a high yield (Sinha & Tandon 2020). Sufficient yield and fertilizer management are major difficulties in maize cropping systems in the northwestern region of Pakistan due to the shortage of irrigation water and poor soil conditions. Soil has some important factors, i.e., organic matter, cation exchange capacity, and pH, which affect this problem (Aziz et al., 2015). Maize has the capacity to produce a significant quantity of potassium fertilizer when compared to other cereal crops. The productivity of maize depends by the quantity of nutrients it requires. Maize will use a significant amount of potassium in an intensive cropping system, making up around 400 kg K2O ha-1. (Kusro and others, 2014). Phosphorus is the second most deficient nutrient in soil after nitrogen (N). The main appearances of phosphorus in soil solution are H2PO4-2 and HPO4-1, but plant uptake of H2PO4- is preferentially compared to HPO4- and in soil solutions, phosphorus concentration varies between 3-300 ppb, while in most plants required phosphorus concentration ranges from 0.3 to 0.6% .And phosphorus deficiency is one of the most deficient factor crop yield and about 25-30% of world's arable land is consider to contain low P for plant growth (Vance et al., 2003). Phosphorus availability is severely low in alkaline and calcareous soil due to high CaCO3 (phosphate ion precipitate as calcium phosphate) and high pH (Li et al., 2023). Plant development, yield, nutrient absorption, and use are all impacted by environmental P and K concentrations (Tian et al., 2017). Potassium (K) is a crucial nutrient which plays a significant role in many bio-chemical, morphological processes. It also plays a vigorous role in photosynthesis (Igras and danyte, 2007). K increase resistance against drought and enhance root growth. Its major role in charge balance, osmoregulation and enzyme activation (Chakmak, 2005). Sixty different enzymes are activated by K that is involved in plant growth. K helps the molecules for exposing appropriate active site for reactions. A sufficient supply of K is necessary for better mechanism of enzyme (Taiz and Zeiger, 2010).

Material and Methods

A pot experiment was conducted in wire house at the Institute of Soil and Environmental Sciences, University of Agriculture, Faisalabad during the month of April, 2015 for seven weeks. This experiment was designed to evaluate the Effect of potassium application on phosphorus use efficiency in maize crop (*Zea mays* L.).

Collection and Preparation of Soil

Bulk soil samples were collected from Agronomy field, University of Agriculture, Faisalabad. Soil was air-dried and ground to pass through 2.0 mm sieve. The soil was thoroughly mixed for homogenization. Then 20 kg soil was added in each pot. Nursery was grown in sand. After three days, nursery were transplanted in the pots. As per pot three plants were kept and each pot.

Treatments

Recommended doses of fertilizer were used as urea, K_2O, and different source of P_2O_5, rock phosphate, single super phosphate, and di-ammonium phosphate at the rate of 110: 80: 125 kg NPK ha^{-1} respectively. K with recommended (3 g pot^{-1}) and double dose of recommended was applied. So total 27 pots were used and total number of treatment were nine.

Treatment used in the pot experiments

Treatment No. Fertilizer application

T_1 P1(DAP)
T_2 P1(DAP) K1 (recommended)
T_3 P1(DAP) K2 (Double recommended)
T_4 P2 (Rock phosphate)
T_5 P2 (Rock phosphate) K1 (recommended)
T_6 P2 (Rock phosphate) K2 (Double recommended)
T_7 P3 (Single super phosphate)
T_8 P3 (Single super phosphate) K1 (recommended)

T_9 P3 (Single super phosphate) K2 (Double recommended)

Irrigation

The crop was irrigated with tap water at 60% of water holding capacity of soil.

Plant Analysis

Maize was sown 10 seed in 20 kg soil of each pot, after germination five seeds were left after thinning. From five plants in each pot, after seven weeks harvested. The treatment were ten.

1. Physical parameters
2. Shoot length (cm)
3. Shoot fresh weight (g)
4. Shoot dry weight (g)
5. Root fresh weight (g)
6. Root dry weight (g)
7. Sample preparation
8. Wet digestion
9. Shoot Potassium Concentration (mg kg^{-1})
10. Shoot/root phosphorus concentration
11. Phosphorus uptake by root (mg)
12. Phosphorus uptake by shoots (mg)
13. Total uptake by shoots and roots (mg)

Statistical Analysis

Effects of potassium application on phosphorus use efficiency in Maize crop were analyzed using two-way ANOVA and the difference among the treatment means were compered by using. Least significant difference (LSD) test at 5% significance level. (Steel *et al.,* 1997) using the software 8.1.ink.

Results

Phosphorus (P) and potassium (K) are the major element, which are required in relatively in large amount and can be termed as macronutrients (Foth, 1984). These are very indispensable for normal growth of plants and yield and also for human and animal health. Their availability in soil and their uptake to plant is an important aspect to study. A number of physical and chemical factors are responsible for availability of P. So, for this experiment was conducted in wire house and different chemical analysis are done to (1) to increase the acquisition of Phosphorus, (2) to check the interaction of K and P and impact of K on the availability of P.

Plant Height

Table. 1 The plants in which we applied DAP with double rate of potassium gives increase shoot length as compared to other treatments. The plants treated with rock phosphate with no potassium give more shoot length as compared to plants in which we apply rock phosphate with recommended and double potassium concentration. The plants receiving SSP without potassium and with recommended dose of potassium gives more shoot length as compared to plants in which we apply SSP with double potassium dose. The minimum shoot length was observed in plants in which we apply rock phosphate with recommended potassium rate.

Table.1 Analysis of variance (ANOVA) for shoot length influenced by K application.

Source	DF	SS	MS	F	P
K	2	120.73	60.366	2.43	0.1161
P	2	127.87	63.935	2.58	0.1038
K*P	4	1024.25	256.062	10.32	0.0002
Error	18	446.73	24.818		
Total	28	1719.58			

Grand Mean = 85.83

Source	DF	SS	MS	F	P
K	2	5002.2	2501.09	6.27	0.0086
P	2	6120.2	3060.09	7.67	0.0039
K*P	4	9547.6	2386.91	5.98	0.0030
Error	18	7179.6	398.87		
Total	26	27849.6			

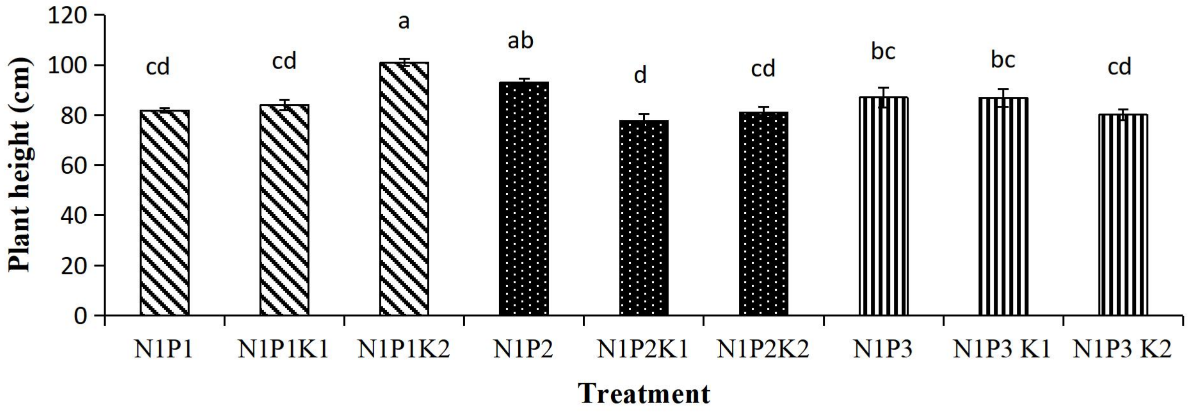

Figure.1 Influence of potassium application on plant height in maize crop where T_1= P_1 (P with DAP source used @ 80 kg ha^{-1}) T_2= P_1K_1 (P with DAP Source and where PK @ 80:125 kg ha^{-1} were used) T_3= P_1K_2 (P with DAP Source PK @ 80:125 kg ha^{-1}) T_4= P_2 (P with R.P source P @ 80 kgha^{-1} were used) T_5= P_2K_1 (P with R.P source and PK @ 80:125 kg ha^{-1}) T_6= P_2 K_2(P with R.P and PK @ 80:125 kg ha^{-1}) T_7= P_3 (P with SSP source and NP @ 80 kg ha^{-1} were used) T_8= P_3K_1(P with SSP source, PK @ 80:125 kg ha^{-1}) $T_{9=}$ P_3K_2 (P with SSP source and PK @ 80:125 kg ha^{-1} were used of PK), whereas column show mean of three replication and bars show standard error. Column sharing the similar letter (s) do not differ significantly at p<0.05 according to LSD test.

Fresh Shoot Weight

Table. 2 The plants in which we applied P (DAP) with double recommended dose of potassium showed maximum fresh weight as compared to other treatments. The treatment where, we applied single super phosphate with no potassium gives better results as compared to those where single super phosphate with recommended and double recommended dose of potassium were applied. While, where rock phosphate with recommended and double recommended dose were applied showed similar results, but minimum result is observed in, where rock phosphate with recommended dose of potassium were applied. Data regarding fresh shoot weight indicates significant effect of applied treatments of phosphorus (DAP) source in combination with double rate potassium. If means are compared a non-sequential trend increased, that is observed from the data mentioned in Figure 2.

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Table 2. Analysis variance (ANOVA) for fresh shoot weight influenced by potassium application. Grand Mean = 120.05

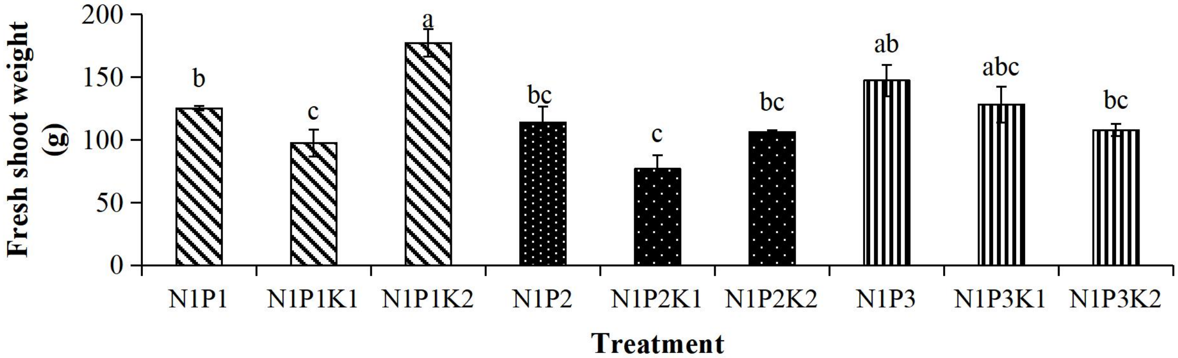

Figure. 2 Influence of potassium application on fresh shoot weight in maize crop where $T_1 = P_1$ (P with DAP source used @ 80 kg ha^{-1}) $T_2 = P_1K_1$ (P with DAP Source and where PK @ 80:125 kg ha^{-1} were used) $T_3 = P_1K_2$ (P with DAP Source PK @ 80:125 kg ha^{-1}) $T_4 = P_2$ (P with R.P source NP @110:80 kgha^{-1} were used) $T_5 = P_2K_1$ (P with R.P source and PK @ 80:125 kg ha^{-1}) $T_6 = P_2K_2$(P with R.P and PK @ 80:125 kg ha^{-1}) $T_7 = P_3$ (P with SSP source and NP @ 80 kg ha^{-1} were used) $T_8 = P_3K_1$(P with SSP source, PK @ 80:125 kg ha^{-1}) $T_9 = P_3K_2$ (P with SSP source and PK @ 80:125 kg ha^{-1} were used of PK), whereas column show mean of three replication and bars show standard error. Column sharing the similar letter (s) do not differ significantly at $p<0.05$ according to LSD test.

Dry Shoot Weight

Table. 3 The Figure 3. showed that treatment where DAP with double recommended dose of potassium were applied recorded increased in shoot dry weight as compared to other all treatments, and also from that where DAP with recommended rate of potassium were treated. While, where rock phosphate and double dose of potassium were applied showed better results as compared to that rock phosphate with and recommended dose of potassium were applied. In last three treatments where single super phosphate source of phosphorus with recommended and double dose of potassium were applied showed almost similar result while, minimum result was recorded where rock phosphate with recommended rate of potassium were applied. Data regarding dry shoot weight indicates significant effect of applied treatments of phosphorus (DAP) source in combination with double dose potassium. If means are compared a non-sequential trend increased, that is observed from the data mentioned in Figure 3.

Table 3. Analysis variance (ANOVA) for dry shoot weight influenced by potassium application.

Source	DF	SS	MS	F	P
K	2	120.039	60.0195	24.97	0.0000
P	2	73.084	36.5420	15.20	0.0001
K*P	4	103.433	25.8583	10.76	0.0001
Error	18	339.822	2.4036		
Total	26				

Grand Mean = 14.622

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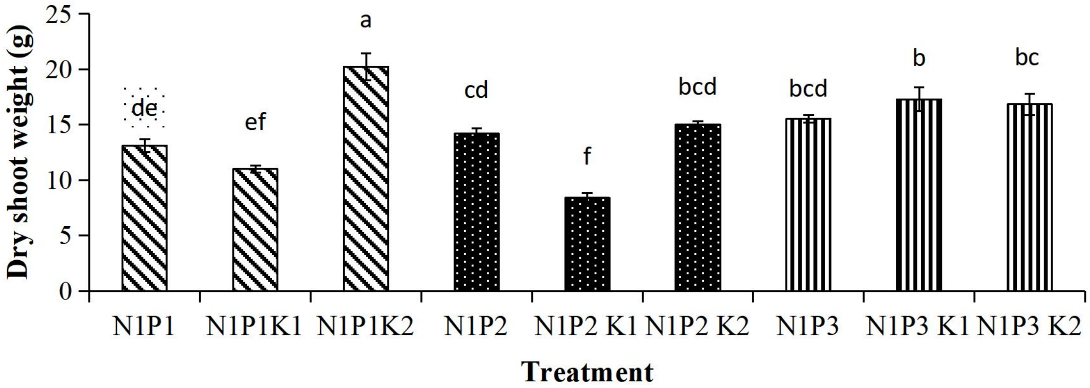

Figure 3. Influence of potassium application on dry shoot weight in maize crop whereT_1= P_1 (P with DAP source used @ 80 kg ha^{-1}) T_2= P_1K_1 (P with DAP Source and where PK @ 80:125 kg ha^{-1} were used) T_3= P_1K_2 (P with DAP Source PK @ 80:125 kg ha^{-1}) T_4= P_2 (P with R.P source NP @110:80 kgha^{-1} were used) T_5= P_2K_1 (P with R.P source and PK @ 80:125 kg ha^{-1}) T_6= P_2 K_2(P with R.P and PK @ 80:125 kg ha^{-1}) T_7= P_3 (P with SSP source and NP @ 80 kg ha^{-1} were used) T_8= P_3K_1(P with SSP source, PK @ 80:125 kg ha^{-1}) T_9= P_3K_2 (P with SSP source and PK @ 80:125 kg ha^{-1} were used of PK), whereas column show mean of three replication and bars show standard error. Column sharing the similar letter (s) do not differ significantly at p<0.05 according to LSD test.

Fresh root weight

Table 4. The plants in which phosphorus (DAP) with double dose of potassium was applied showed increased in fresh root weight than, which were treated with DAP and recommended dose of potassium. And where rock phosphate and single super were applied with recommended and double dose potassium showed similar result.

Table 4 Analysis variance (ANOVA) for fresh root weight influenced by potassium application.

Source	DF	SS	MS	F	P
K	2	1253.90	626.950	2.66	0.0971
P	**2**	469.66	234.830	1.00	0.3885
K*P	4	772.86	193.216	0.82	0.5290
Error	18	4239.64	235.535		
Total	26	6736.06			

Grand Mean = 51.323

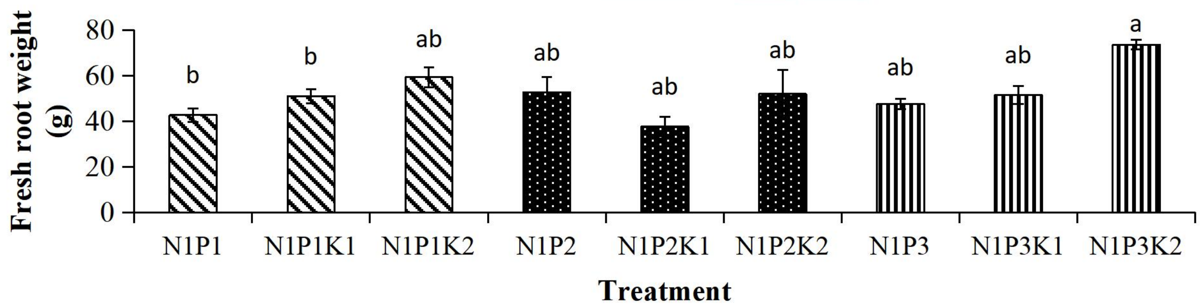

Figure 4. Influence of potassium application on fresh root weight in maize crop where T_1= P_1 (P with DAP source used @ 80 kg ha^{-1}) T_2= P_1K_1 (P with DAP Source and where PK @ 80:125 kg ha^{-1} were used) T_3= P_1K_2 (P with DAP Source PK @ 80:125 kg ha^{-1}) T_4= P_2 (P with R.P source NP

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@110:80 kgha^{-1} were used) $T_5 = P_2K_1$ (P with R.P source and PK @ 80:125 kg ha^{-1}) $T_6 = P_2 K_2$(P with R.P and PK @ 80:125 kg ha^{-1}) $T_7 = P_3$ (P with SSP source and NP @ 80 kg ha^{-1} were used) $T_8 = P_3K_1$(P with SSP source, PK @ 80:125 kg ha^{-1}) $T_9 = P_3K_2$ (P with SSP source and PK @ 80:125 kg ha^{-1} were used of PK), whereas column show mean of three replication and bars show standard error. Column sharing the similar letter (s) do not differ significantly at $p<0.05$ according to LSD test.

Dry Root Weight

Table. 5 The plant in which DAP source of phosphorus with double dose of potassium was applied showing increased dry root weight as compared to other which are treated with no and potassium recommended dose were applied, but also where single super phosphate with double dose of potassium were applied observed better result as compared to those where, single super phosphate and recommended potassium were applied, while rock phosphate with recommended and double dose of potassium applied almost recorded similar results, and also among all treatments where, rock phosphate with recommended dose of potassium were applied showed minimum dry weight. Data regarding dry root weight indicates significant effect of applied treatments of phosphorus (DAP) source in combination along double rate potassium. If means are compared a non-sequential trend increased, that is observed from the data mentioned in Figure 5.

Table 5. Analysis of variance for dry root weight influenced by Potassium application.

Source	DF	SS	MS	F	P
K	2	321.23	160.613	10.54	0.0009
P	2	415.17	207.583	13.63	0.0002
K*P	4	46.39	11.599	0.76	0.5639
Error	18	274.22	15.234		
Total	26	1057.00			

Grand Mean = 15.897

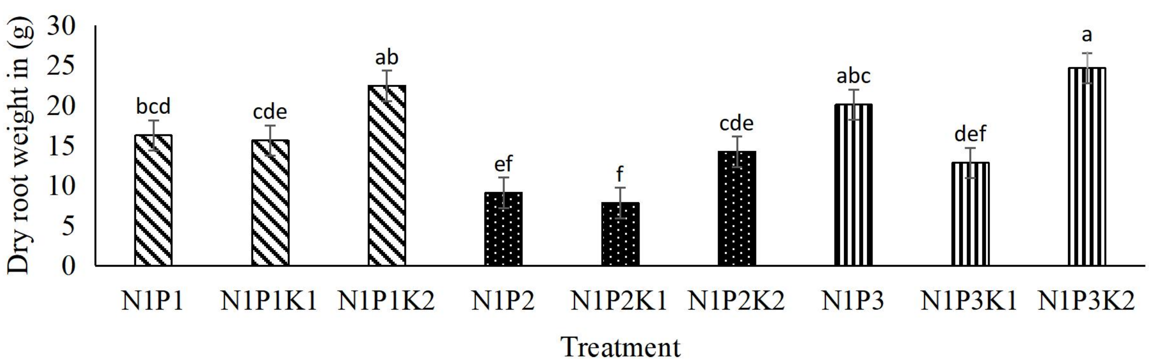

Figure 5. Influence of potassium application on dry root weight in maize crop where $T_1 = P_1$ (P with DAP source used @ 80 kg ha^{-1}) $T_2 = P_1K_1$ (P with DAP Source and where PK @ 80:125 kg ha^{-1} were used) $T_3 = P_1K_2$ (P with DAP Source PK @ 80:125 kg ha^{-1}) $T_4 = P_2$ (P with R.P source NP @110:80 kgha^{-1} were used) $T_5 = P_2K_1$ (P with R.P source and PK @ 80:125 kg ha^{-1}) $T_6 = P_2 K_2$(P with R.P and PK @ 80:125 kg ha^{-1}) $T_7 = P_3$ (P with SSP source and NP @ 80 kg ha^{-1} were used) $T_8 = P_3K_1$(P with SSP source, PK @ 80:125 kg ha^{-1}) $T_9 = P_3K_2$ (P with SSP source and PK @ 80:125 kg ha^{-1} were used of PK), whereas column show mean of three replication and bars show standard error. Column sharing the similar letter (s) do not differ significantly at $p<0.05$ according to LSD test.

K concentration in Shoot

Table 6. The plant in which we applied rock phosphate source of phosphorus with double recommended potassium showed maximum concentration as compared to T_5 and T_4 in which

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applied rock phosphate with recommended dose of potassium, but other treatments where DAP with recommended and double of potassium received treatment showed similar result almost and also the other treatment which are treated with single super phosphate and potassium recommended and double dose showed non-significant results while only low concentration is observed in control T_1 as compared to other treatments.

Table 6. Analysis of variance (ANOVA) for K concentration in shoot influenced by potassium application.

Source	DF	SS	MS	F	P
K	2	4.974E+08	2.487E+08	0.62	0.5486
P	2	6.696E+07	3.348E+07	0.08	0.9202
K*P	4	1.368E+09	3.420E+08	0.85	0.5100
Error	18	7.210E+09	4.005E+08		
Total	26	9.142E+09			

Grand Mean = 46822

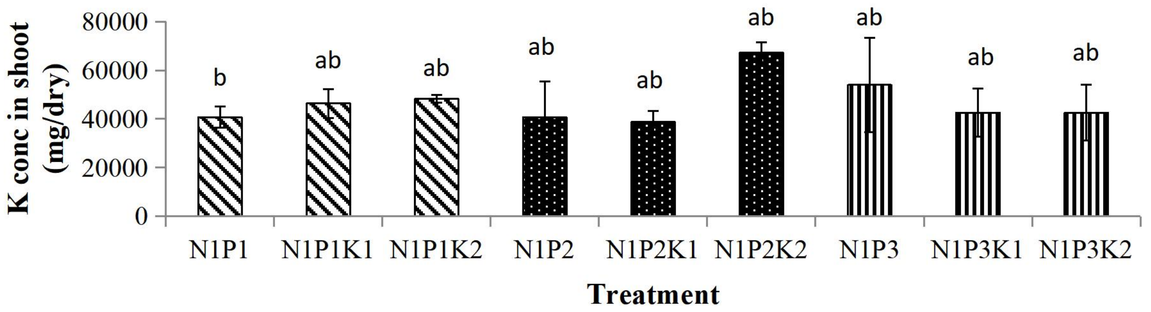

Figure 6. Influence of potassium application on K concentration in shoot in maize crop where T_1= P_1 (P with DAP source used @ 80 kg ha^{-1}) T_2= P_1K_1 (P with DAP Source and where PK @ 80:125 kg ha^{-1} were used) T_3= P_1K_2 (P with DAP Source PK @ 80:125 kg ha^{-1}) T_4= P_2 (P with R.P source NP @110:80 kgha^{-1} were used) T_5= P_2K_1 (P with R.P source and PK @ 80:125 kg ha^{-1}) T_6= P_2 K_2(P with R.P and PK @ 80:125 kg ha^{-1}) T_7= P_3 (P with SSP source and NP @ 80 kg ha^{-1} were used) T_8= P_3K_1(P with SSP source, PK @ 80:125 kg ha^{-1}) T_9= P_3K_2 (P with SSP source and PK @ 80:125 kg ha^{-1} were used of PK), whereas column show mean of three replication and bars show standard error. Column sharing the similar letter (s) do not differ significantly at p<0.05 according to LSD test.

K concentration of root

Table 7. Plants in which we applied single super phosphorus with double dose of potassium recorded higher concentration of potassium as compared to that where single super phosphate with recommended dose of K, while double and recommended dose of potassium with rock phosphate showing less concentration of potassium than where rock phosphate were applied, and the treatment which was treated with DAP and potassium recommended and double showed similar result but in overall treatments while treatment which received single super phosphate showing minimum concentration of potassium.

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Table 7. Analysis of variance (ANOVA) for K concentration of root influenced by potassium application.

Source	DF	SS	MS	F	P
K	2	4.544E+07	2.272E+07	0.47	0.6295
P	2	3.109E+07	1.554E+07	0.32	0.7267
K*P	4	7.007E+08	1.752E+08	3.66	0.0237
Error	18	1.752E+08	4.783E+07		
Total	26	4.783E+07			

Grand Mean = 22622

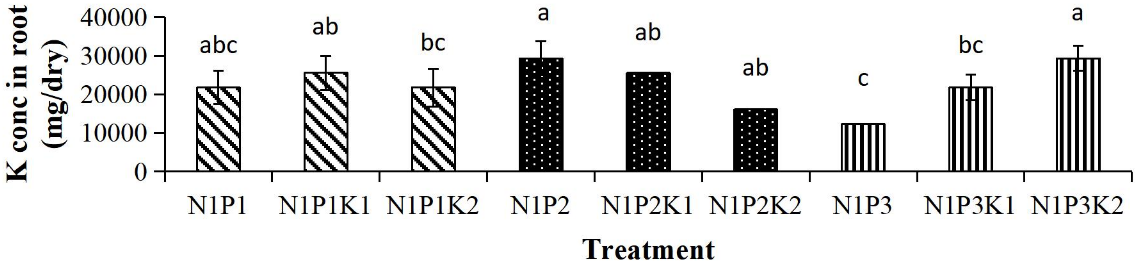

Figure 7 Influence of potassium application on K concentration in root in maize crop where $T_1= P_1$ (P with DAP source used @ 80 kg ha^{-1}) $T_2= P_1K_1$ (P with DAP Source and where PK @ 80:125 kg ha^{-1} were used) $T_3= P_1K_2$ (P with DAP Source PK @ 80:125 kg ha^{-1}) $T_4= P_2$ (P with R.P source NP @110:80 kgha^{-1} were used) $T_5= P_2K_1$ (P with R.P source and PK @ 80:125 kg ha^{-1}) $T_6= P_2 K_2$(P with R.P and PK @ 80:125 kg ha^{-1}) $T_7= P_3$ (P with SSP source and NP @ 80 kg ha^{-1} were used) $T_8= P_3K_1$(P with SSP source, PK @ 80:125 kg ha^{-1}) $T_9= P_3K_2$ (P with SSP source and PK @ 80:125 kg ha^{-1} were used of PK), whereas column show mean of three replication and bars show standard error. Column sharing the similar letter (s) do not differ significantly at $p<0.05$ according to LSD test.

P concentration in shoot

Table 8. The plant in which we have applied DAP and double dose of potassium showed increased in phosphorus concentration as compared to that where DAP and recommended rate of potassium was applied, while the treatment in which rock phosphate with recommended potassium and double rate of potassium were applied indicate similar results and in the last three treatments in which single super phosphate with recommended and double recommended dose were applied showed similar concentration of phosphorus, but in all treatments where DAP with recommended dose of potassium and no potassium was applied recorded in minimum concentration of phosphorus. Data regarding P concentration in shoot indicates significant effect of applied treatments phosphorus (DAP) source in combination with double rate potassium applied. If means are compared a non-sequential trend of increased that is observed from the data mentioned in Figure 8.

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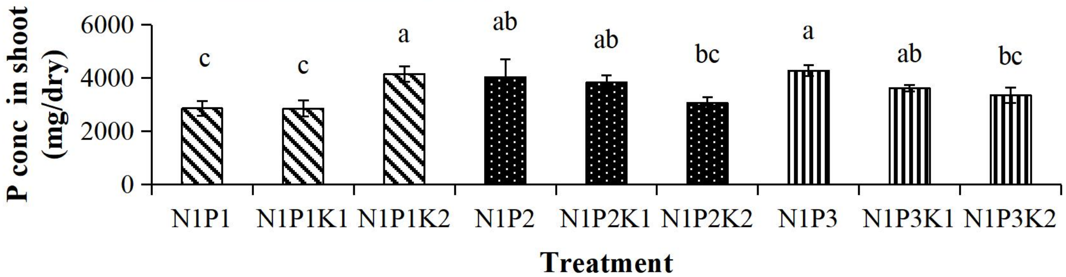
Table 8. Analysis of variance (ANOVA) for P concentration of shoot influenced by potassium application.

Source	DF	SS	MS	F	P
K	2	383124	191562	0.49	0.6206
P	2	1053286	526643	1.35	0.2850
K*P	4	5840905	1460226	3.73	0.0221
Error	18	7037863	390992		
Total	26	1431E+07			

Grand Mean= 3529.7



Source	DF	SS	MS	F	P
K	2	53153	26577	0.17	0.8411
P	2	66859	33429	0.22	0.8048
K*P	4	589357	147339	0.97	0.4486
Error	18	2737045	152058		
Total	26	3446415			

Figure 8. Influence of potassium application on P concentration in shoot in maize crop where $T_1 = P_1$ (P with DAP source used @ 80 kg ha^{-1}) $T_2 = P_1K_1$ (P with DAP Source and where PK @ 80:125 kg ha^{-1} were used) $T_3 = P_1K_2$ (P with DAP Source PK @ 80:125 kg ha^{-1}) $T_4 = P_2$ (P with R.P source NP @110:80 kgha^{-1} were used) $T_5 = P_2K_1$ (P with R.P source and PK @ 80:125 kg ha^{-1}) $T_6 = P_2K_2$(P with R.P and PK @ 80:125 kg ha^{-1}) $T_7 = P_3$ (P with SSP source and NP @ 80 kg ha^{-1} were used) $T_8 = P_3K_1$(P with SSP source, PK @ 80:125 kg ha^{-1}) $T_9 = P_3K_2$ (P with SSP source and PK @ 80:125 kg ha^{-1} were used of PK), whereas column show mean of three replication and bars show standard error. Column sharing the similar letter (s) do not differ significantly at $p<0.05$ according to LSD test.

P concentration in root

Table 9. The plants in which we applied three source of phosphorus as DAP, rock phosphate and single super phosphate and three treatment of potassium showed similar results. Data regarding P concentration in root indicates non-significant effect of applied treatments of phosphorus fertilizer with three source in combination with the applied potassium levels. If means are compared a non-sequential trend of increased that is observed from the data mentioned in figure 9.

Table 4.9 Analysis of variance (ANOVA) for P concentration of root influenced by Potassium.

Grand Mean= 2380.5

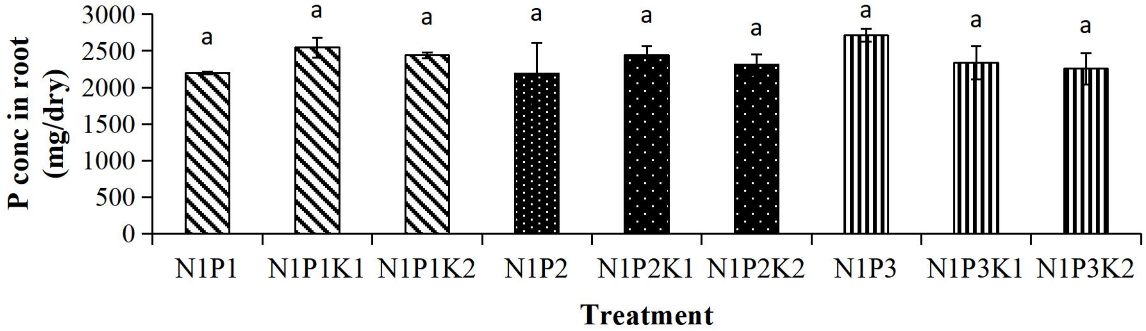


Figure 9. Influence of potassium application on P concentration in root in maize crop where $T_1= P_1$ (P with DAP source used @ 80 kg ha^{-1}) $T_2= P_1K_1$ (P with DAP Source and where PK @ 80:125 kg ha^{-1} were used) $T_3= P_1K_2$ (P with DAP Source PK @ 80:125 kg ha^{-1}) $T_4= P_2$ (P with R.P source NP @110:80 kgha^{-1} were used) $T_5= P_2K_1$ (P with R.P source and PK @ 80:125 kg ha^{-1}) $T_6= P_2 K_2$(P with R.P and PK @ 80:125 kg ha^{-1}) $T_7= P_3$ (P with SSP source and NP @ 80 kg ha^{-1} were used) $T_8= P_3K_1$(P with SSP source, PK @ 80:125 kg ha^{-1}) $T_9= P_3K_2$ (P with SSP source and PK @ 80:125 kg ha^{-1} were used of PK), whereas column show mean of three replication and bars show standard error. Column sharing the similar letter (s) do not differ significantly at p<0.05 according to LSD test.

P uptake in shoot

Table 10. The plants in which we applied DAP with double dose of potassium showed maximum uptake of phosphorus concentration in shoot as compared to all other treatments. While, where rock phosphate and recommended potassium showed low P uptake as compared to that rock phosphate and double dose potassium were applied but also where single super phosphate with recommended and double recommended have similar results, while minimum result was recorded in plants where only DAP and rock phosphate were applied.

Table.10 Analysis variance for P uptake in shoot influenced by potassium application.

Source	DF	SS	MS	F	P
K	2	1444.43	722.21	4.47	0.0266
P	2	700.28	350.14	2.17	0.1435
K*P	4	4688.54	1172.13	7.25	0.0012
Error	18	2908.80	161.60		
Total	26	9742.04			

Grand Mean = 52.737

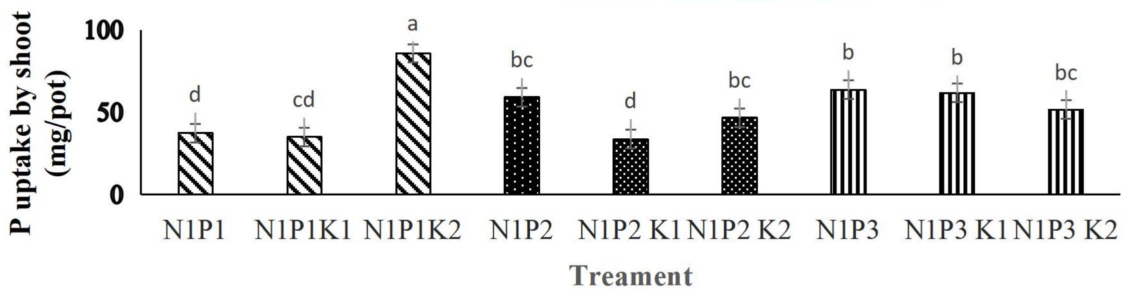


Figure 10 Influence of potassium application on P uptake by shoot in maize crop where $T_1= P_1$ (P with DAP source used @ 80 kg ha^{-1}) $T_2= P_1K_1$ (P with DAP Source and where PK @ 80:125 kg ha^{-1}

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were used) $T_3= P_1K_2$ (P with DAP Source PK @ 80:125 kg ha^{-1}) $T_4= P_2$ (P with R.P source NP @110:80 $kgha^{-1}$ were used) $T_5= P_2K_1$ (P with R.P source and PK @ 80:125 kg ha^{-1}) $T_6= P_2 K_2$(P with R.P and PK @ 80:125 kg ha^{-1}) $T_7= P_3$ (P with SSP source and NP @ 80 kg ha^{-1} were used) $T_8= P_3K_1$(P with SSP source, PK @ 80:125 kg ha^{-1}) $T_9= P_3K_2$ (P with SSP source and PK @ 80:125 kg ha^{-1} were used of PK), whereas column show mean of three replication and bars show standard error. Column sharing the similar letter (s) do not differ significantly at $p<0.05$ according to LSD test.

P uptake in roots

Table 11. The plant in which we applied phosphorus (DAP) source along with double recommended dose of potassium along DAP recorded maximum P uptake as compared other treatments and also where we applied SSP source of phosphorus showed better result as compared to those in which we applied SSP and recommended dose of potassium. Minimum P uptake was recorded in where rock phosphate source of P and recommended rate of potassium fertilizers were applied. Data regarding P indicates significant effect of applied treatments of phosphorus fertilizer with DAP source in combination with the applied double rate of potassium. If means are compared a non-sequential trend of increased, that is observed from the data mentioned in Figure 11.

Table 4.11 Analysis variance for P uptake in root influenced by potassium application.

Source	DF	SS	MS	F	P
K	2	1722.97	861.49	10.44	0.0010
P	2	2686.29	1343.14	16.28	0.0001
K*P	4	326.91	81.73	0.99	0.4377
Error	18	1484.90	82.49		
Total	26	6221.07			

Grand Mean= 37.286

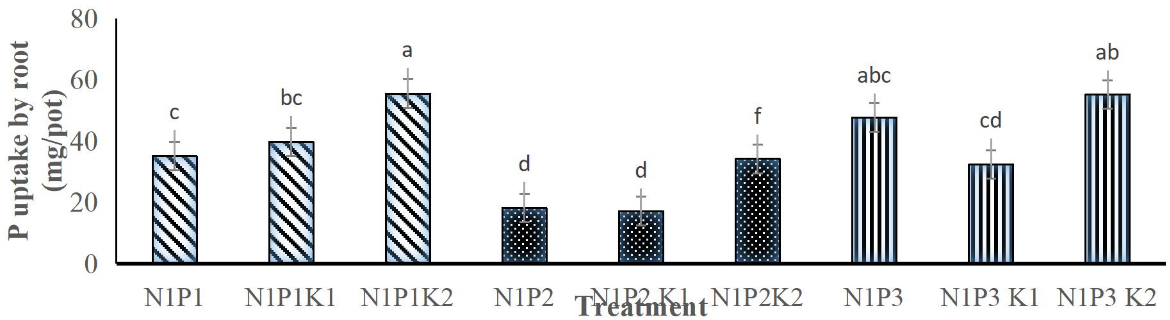

Figure 11. Influence of potassium application on P uptake by root in maize crop where $T_1= P_1$ (P with DAP source used @ 80 kg ha^{-1}) $T_2= P_1K_1$ (P with DAP Source and where PK @ 80:125 kg ha^{-1} were used) $T_3= P_1K_2$ (P with DAP Source PK @ 80:125 kg ha^{-1}) $T_4= P_2$ (P with R.P source NP @110:80 $kgha^{-1}$ were used) $T_5= P_2K_1$ (P with R.P source and PK @ 80:125 kg ha^{-1}) $T_6= P_2 K_2$(P with R.P and PK @ 80:125 kg ha^{-1}) $T_7= P_3$ (P with SSP source and NP @ 80 kg ha^{-1} were used) $T_8= P_3K_1$(P with SSP source, PK @ 80:125 kg ha^{-1}) $T_9= P_3K_2$ (P with SSP source and PK @ 80:125 kg ha^{-1} were used of PK), whereas column show mean of three replication and bars show standard error. Column sharing the similar letter (s) do not differ significantly at $p<0.05$ according to LSD test.

Total P uptake

Table 12. The plant in which we applied phosphorus DAP source along with double rate of

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potassium recorded maximum concentration of P as compared to other treatments, and also where, applied rock phosphate with recommended potassium showed better result than where double dose of potassium with rock phosphate were applied. While in last three treatments which treated with SSP and recommended potassium higher concentration as compared to that in which SSP with double rate of potassium was applied, but minimum concentration was recorded were only DAP with phosphorus source were applied.

Table 12. Analysis variance for Total P uptake in shoot and root influenced by potassium application.

Source	DF	SS	MS	F	P
K	2	287108	143554	0.36	0.7004
P	2	1147026	573513	1.45	o.2605
K*P	4	8146175	2036544	5.15	0.0060
Error	18	71146175	39257		
Total	26	1.669709			

Grand Mean =5939.2

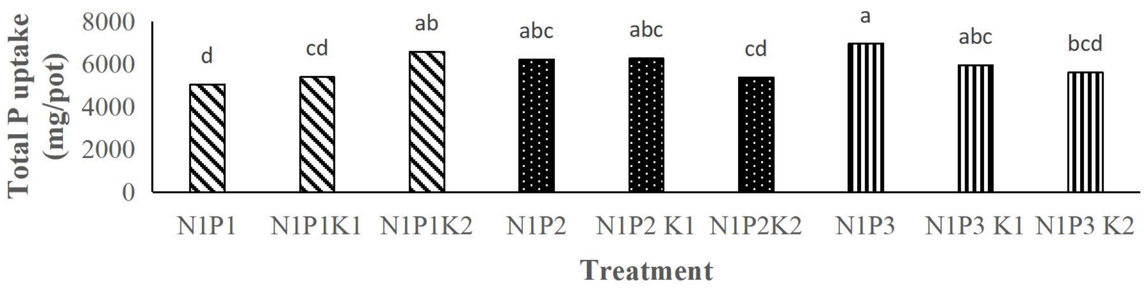

Figure 12. Influence of potassium application on total P uptake by root and shoot in maize crop where $T_1= P_1$ (P with DAP source used @ 80 kg ha^{-1}) $T_2= P_1K_1$ (P with DAP Source and where PK @ 80:125 kg ha^{-1} were used) $T_3= P_1K_2$ (P with DAP Source PK @ 80:125 kg ha^{-1}) $T_4= P_2$ (P with R.P source NP @110:80 kgha^{-1} were used) $T_5= P_2K_1$ (P with R.P source and PK @ 80:125 kg ha^{-1}) $T_6= P_2 K_2$(P with R.P and PK @ 80:125 kg ha^{-1}) $T_7= P_3$ (P with SSP source and NP @ 80 kg ha^{-1} were used) $T_8= P_3K_1$(P with SSP source, PK @ 80:125 kg ha^{-1}) $T_9= P_3K_2$ (P with SSP source and PK @ 80:125 kg ha^{-1} were used of PK), whereas column show mean of three replication and bars show standard error. Column sharing the similar letter (s) do not differ significantly at $p<0.05$ according to LSD test.

Discussion

Among the essential nutrient, phosphorus (P) is the most important regarding availability to plants in soil Santhosha (2013). This element is usually abundant in soil but mostly reactive nature, the amount of phosphorus in available form to plant is a deficient factor (Sidharam et al., 2017). Phosphorus deficiency leads to slower and often retard growth and decreases the yield. Phosphorus is added to soil in the form of phosphate fertilizer but the overall phosphorus use efficiency is low due to fraction of soluble phosphorus is used by plants and rapidly form insoluble complexes with other soil constituents. Therefore, frequent application of soluble form of inorganic phosphorus is needed. The current investigation was performed to evaluate the effect of potassium application on phosphorus use efficiency. Two levels of potassium along with three different source of phosphorus i.e. Di-ammonium phosphate (DAP), rock phosphate (RP) and single super phosphate (SSP) was used by following the CRD design. The maize plants were harvested at maximum vegetative growth stage before the initiation of reproductive stage. The agronomic and physiological parameters of plant were measured at maximum vegetative growth stage. It was observed that plant height, fresh and dry weight of root and shoot were increased by apply DAP phosphorus source along double rate of potassium showed in (Figure 1, 2, 3, 4, 5,) Plant height, fresh shoot and root, dry shoot and root were increased by influence of potassium and phosphorus. This increase in plant height might be due to stimulatory effect of P (DAP) source allows more P in the solution phase that ultimately will be available for growth of root (Atheefa Munawery., 2013; Murphy and sanders, 2007). Fresh and dry weight of root and shoot was might be increased due to positive response of potassium which increase the availability of P and therefore, photosynthesis and photosynthate. Dry matter was enhanced by production of photosynthate (Anonymous, 2014,). (Wakeel and Ishfaq 2022) they reported that K application showed maximum fresh shoot and root weight. (Gobarah et al., 2011) also expressed that application of K fertilizer significantly increase all agronomic parameters. The release of protons from roots increased under P deficiency; this would facilitate acquisition of P from rhizosphere soil, especially in soils containing Ca-phosphates such as neutral and calcareous soils, fertilized with phosphate (Zhan et al., 2016 Majumdar et al., 2017). Where plasma lemma H^+ pump permanently releasing H^+ ions. Transportation of water, nutrients, metabolites and phytohormones is done by potassium throughout xylem and phloem (Portela et al., 2019). Maximum potassium concentration in shoot and root (Figure 6 and 7) by phosphorus and potassium different levels might be due to positive effect of phosphorus, when P was increased, the potassium may also increase because some nutrients have synergistic effect with each other. So, results indicate that P increase K concentration, are in line with (Shakeri and Abtahi, 2018). found that there was increase in K contents of whenever amount of P rate increased. These changes might be due to prolonged and steady availability of P to plants. (Lu et al., 2022) suggested that slow releasing of phosphatic fertilizer increase in K contents in plant. And another line also suggested that the increasing levels of potassium increase the concentrations and the uptake of potassium into shoots and roots (Celik et al., 2010). Similar results are also reported by (Tan et al., 2017). They reported that highest K concentration in shoot was recorded in case of potassium with different levels. P concentration in shoot and root (Figure 4.8, 4.9) was recorded maximum by applying DAP source of P at double rate potassium. It might be due to synergistic effect of K with P by reducing chance of fixation and increasing proton release, P uptake was increased. Because of high uptake, P root to shoot improved and therefore P concentration in shoot was maximum. The interaction of K with P (DAP) source of fertilizer which reduces its fixation with increase P availability (Mubarak et al., 2016) reported that more availability of P also promotes the uptake of P from the soil. It observed that P translocation was maximum (4.9) where, DAP source of phosphorus with double dose of potassium were applied. It might be because of K double rate by releasing high amount of proton and reducing the fixation of P with soil colloids and improve its availability. So improved uptake of P which increase root growth, (Adilson et al., 2017) reported that more availability of P also promote uptake of P. P uptake concentration in shoot and root (4.10, 4.11) was observed maximum where DAP phosphorus source along double rate of potassium were applied, It might be due to synergistic effect of K with P by reducing chance of fixation and increasing proton release, P uptake was increased. Because of high uptake, P root to shoot improved and therefore P concentration in shoot was maximum. The interaction of K with P (DAP) source of fertilizer which reduce its fixation and increase P availability (DoVale*,* 2013) (Khan et al., 2018) reported that more availability of P also promotes the uptake of P from the fertilizers. It observed that P translocation was maximum (4.11) where, DAP source of phosphorus with double dose of potassium were applied. It might be because of K double rate by releasing high amount of proton and reducing the fixation of P with soil colloids and improve P availability. The release of protons from roots increased under P deficiency; this would facilitate acquisition of P from rhizosphere soil, especially in soils containing Ca-phosphates such as neutral and calcareous soils, fertilized with phosphate (Delgado et al., 2017); (Roberts, and Johnston 2015). Where plasma lemma H^+

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pump permanently releasing H^+ ions. Transportation of water, nutrients, metabolites and phytohormones is done by potassium throughout xylem and phloem (Lollato et al., 2019). The total P in shoot and root (4.12) was recorded maximum were DAP source of phosphorus were used with double dose of potassium. It might be because of double rate of potassium by releasing high amount of proton and reducing the fixation of P with soil colloids and improve its availability. So, more uptake of P increase root growth, (Ramesh et al., 2022) reported that more availability of P also promote uptake of P. Reported that Same results as mentioned above was found by (Correa et al., 2008) who observed that P uptake by plant was highest in case of DAP in comparison with other tested P sources including SSP and R.P. This fact was also confirmed by (Wang et al., 2017) who checked the efficiency of different P fertilizers and found that the P concentration in shoot and root was significantly increased in comparison with control by using all the P sources. (Gordan et al., 2006) reported that increase the presence of P in the soil then uptake also increased. It was also observed that using different rates of NPK and also combined both fertilizer increase efficiency of each other and affects the plant nutrient uptake (Asghar *et al*. 2010).

Conclusion

In conclusion the usage of phosphorus DAP source along with double rate of potassium is most effective, improved the plant growth, and also phosphorus availability and usage is improved. This might be due potassium double rate because to less the fixation of colloid.

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