Asian Journal of Physical and Chemical Sciences

8(4): 14-21, 2020; Article no.AJOPACS.61207
ISSN: 2456-7779

Distribution and Variation of Potassium in Black Soil at Different Stages of Crop Growth in Maize (*Zea mays*)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AJOPACS/2020/v8i430122
Editor(s):
(1) Dr. Natt Makul, Phranakhon Rajabhat University, Thailand.
Reviewers:
(1) Najeba Farhad Salih, Koya University, Iraq.
(2) N. Viji, Tamil Nadu Agricultural University, India.
Complete Peer review History: http://www.sdiarticle4.com/review-history/61207

Original Research Article

Received 20 July 2020
Accepted 26 September 2020
Published 27 October 2020

ABSTRACT

Potassium (K) is the third most important major plant nutrient with numerous functions. The availability of K depends on concentration relative to that of Ca^{2+} and Mg^{2+} than on the total quantity of K present. The level of extraction of K by different extractants followed the order: boiling HNO_3 (1 *M*) > Non- exchangeable K > Exchangeable K > Water soluble K. The amount of K extracted by different extractants was more in non- calcareous soil followed by calcareous soil. To know the K availability in both the soils, a pot culture experiment was conducted with the two soils (i.e., calcareous and non-calcareous) to know the response of maize to K application. Results showed that a significant higher value of available K in calcareous soil under potassium @ 120 kg K_2O ha^{-1} treatment followed by 80 kg K_2O ha^{-1} in non-calcareous soil irrespective of critical growth stages of hybrid maize. Among the K fractions, water soluble K was the least in magnitude and lattice K was found to be dominant one. Application of 120 kg K_2O ha^{-1} recorded the highest potassium in all the K fractions (water soluble K, exchangeable K and nitric acid soluble K) in all stages of crop growth in calcareous soil whereas in non-calcareous soil 80 kg K_2O ha^{-1} recorded high in all the fractions and the results emphasizing the importance of potassium in soil. Grain and straw yield of hybrid maize were significantly higher under 120 kg K_2O ha^{-1}in calcareous soil and 80 kg K_2O ha^{-1} in non-

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calcareous soil which is well evidenced by a yield increase of 37.7 % over control. A significant and positive correlation was existing between all fractions of potassium viz., HNO_3 soluble K, non-exchangeable K, exchangeable K, water soluble K and available K with grain and stover yield in calcareous soil and non- calcareous soil. It was found that calcareous soil showed comparatively better response to the application of potassium especially in water soluble K with an R^2 value of 0.917** followed by HNO_3 soluble K with a R^2 value of 0.895**. Therefore, the present investigation stresses the vital importance of inclusion of higher dose of potassium in calcareous soil for maintaining soil K dynamics and enhancing yield of hybrid maize so as to sustain soil productivity.

Keywords: Potassium; potassium fractions; yield; K uptake; correlation.

1. INTRODUCTION

Potassium (K) is known as quality element and required by plants for healthy growth, but Indian agriculture has traditionally relied on the native soil resource of potassium [1]. Potassium is probably the most pertinent nutrient that has the potential of significantly affecting agricultural production in the country [2]. Historically, low application rates of K in crop have led to over-dependence on the native soil reserve K. Potassium (K), constituting an average of 1.9% of the earth's crust and it is one of the essential macro elements required for growth and development of plants. Potassium increases the protein content of plants, the starch content in grains and tubers, vitamin C and the solid soluble contents in fruits. The crucial importance of K in quality formation confirms its role in promoting the production of photosynthates and their transport to storage organs such as fruits, grains, and tubers and enhancing their conversion into starch, protein, vitamins, and oil [3]. In general, response of crop to applied potassium is very low due to high potassium content of soils derived from basaltic parent material. However, available data in recent years indicate that the magnitude of crop response to potassium in these soils is increasing in areas of higher cropping intensity [4].

Soil K exists in four different forms *viz.,* water soluble-K, most frequently available form to plants; exchangeable-K, held by negative charges on soil colloids and is readily available to plants; non-exchangeable or fixed-K, which is trapped between layers of expanding lattice [5].There is a dynamic equilibrium among different forms of soil potassium and any depletion in a given form would shift the equilibrium in the direction to replenish it [6]. Higher yields and crop quality can be obtained at optimal N: K nutritional ratios.

Continued cropping without adequate application of K leads to depletion of all forms of K [7]. This will adversely affect the K dynamics and may cause constraint for crop production. Due to predominance of kaolinitic clay minerals which cannot fix K and also have low CEC, red and lateritic soils normally have the lowest amounts of all the forms of K [8]. It is evident that in spite of having comparable total K content, K supplying capacity of different soils may vary depending upon the distribution of the different forms of K. Maize is a heavy feeder, of calcium, magnesium and potassium. Presence of one of these elements in large quantities can affect the uptake of other. Relative abundance of different forms of soil K determines the K supplying capacity and K availability to crops. Keeping this in view, the present investigation was undertaken to study the distribution and dynamics of K in calcareous soil and the relationships among different forms of K.

2. MATERIALS AND METHODS

A pot culture experiment was conducted during 2017- 2018 in Department of Soil Science and Agricultural Chemistry, Tamil Nadu Agricultural University, Coimbatore with two types of soil viz., Black calcareous and non-calcareous. The black calcareous soil was taken from Eastern block, TNAU, Coimbatore and it belongs to Periayanaickenpalayam series, taxonomically referred as sandy clay loam, mixed black calcareous *Vertic Ustropept* and non- calcareous soil was taken from farmers field of Ikkarai Boluvampatti village, Thondamuthur block, Coimbatore district of Tamil Nadu and it belongs to Noyyal series, taxonomically referred as fine-loamy, mixed, isohyperthermic, *Typic Haplustalf.* In each pot, one maize plant (CO 6 variety) was maintained at required level of soil moisture.

In calcareous soil, the initial status was found to be medium in organic carbon, low in available N, medium in available P and high in available K status. Among the micronutrients, DTPA Mn found to be sufficient and Fe, Zn and Cu were deficient in calcareous soil (S_1). In non calcareous soil (S_2), the initial status found to be medium in organic carbon, low in available N, high in available P and high in available K status. The K fractions viz., water soluble K, exchangeable K, non- exchangeable K and HNO_3 soluble K details were furnished in the Table 1. There were four treatments each replicated thrice in Completely Randomized Block Design. Based on STCR recommendation, the recommended dose of N, P_2O_5 and graded levels of K were applied. K_2O levels were fixed based on 100% STCR K, 125% STCR K and 150% STCR K which worked out to be 40 kg K_2O ha^{-1} (T_2), 80 kg K_2O ha^{-1} (T_3) and 120 kg K_2O ha^{-1} (T_4) applied in both the soils. Grain yield target of 10 t ha^{-1} was fixed to arrive the 100% STCR-K. The sources of N, P and K used were urea, single super phosphate (SSP) and muriate of potash (MOP).

Table 1. Initial characteristics of black calcareous and non – calcareous soil

Parameters	Calcareous soil (S_1)	Non-calcareous soil (S_2)
pH	8.47	7.91
EC (dS m^{-1})	0.47	0.34
OC(g kg^{-1})	5.20	5.25
Free $CaCO_3$ (%)	12.5	0.50
K fractions (mg kg^{-1})		
Water soluble K	15.7	20.0
Exchangeable K	355	375
Available K	741	790
Non – exchangeable K	392	575
HNO_3 soluble K	752	950
Total K	12975	13574

$$\begin{aligned} FN &= 4.01\,T - 0.76\,SN - 0.83\,ON \\ FP_2O_5 &= 1.57\,T - 2.71\,SP - 0.61\,OP \\ FK_2O &= 2.09\,T - 0.26\,SK - 0.65\,OK \end{aligned}$$

Chart 1. STCR based fertilizer prescription equations for maize

Where, FN, FP_2O_5 and K_2O are fertilizer N, P_2O_5 and K_2O in kg ha^{-1}, respectively; T is the yield target in q ha^{-1}; SN, SP and SK are soil available N, P and K in kg ha^{-1}, respectively and ON, OP and OK are the quantities of N, P and K in kg ha^{-1} supplied through FYM, respectively.

The soil samples were collected periodically at vegetative, tasseling and harvest stages of maize for chemical analysis. The dried samples were analyzed for K parameters (water soluble K, exchangeable K, non-exchangeable K and nitric acid soluble K). For determination of water soluble-K, exchangeable-K and non-exchangeable-K, procedures given by [9], [10], [11] were followed, respectively. The potassium content of the extract was determined using flame photometer.

3. RESULTS AND DISCUSSION

3.1 Water Soluble K

The water soluble-K content was found to be significantly affected by potassium application. In calcareous soil (S_1) and in non- calcareous soil (S_2), the water-soluble K varied from 10.3 to 12.6 and 17.1 to 18.1 ppm (vegetative), 8.90 to 11.2 and 14.6 to 16.0 ppm (tasseling) and 6.25 to 8.77 and 10.4 to 12.1 ppm (harvest), respectively (Table 2). It was observed that with the increase in potassium levels, the water soluble K content also increased significantly and showed decreasing trend from vegetative to harvest stages of maize in both the soil types. Non-calcareous soil recorded the higher water-soluble K in all the three stages of crop growth indicating the capability of the non-calcareous soil to release higher water-soluble K in all the stages of crop growth than calcareous soil. Application of potassium @ 120 kg K_2O ha^{-1} resulted in higher water-soluble K in calcareous soil (S_1) which was on par with potassium @ 80 kg K_2O ha^{-1} in non-calcareous soil (S_2). The potassium application increased the water-soluble K content significantly over control in all the treatment combinations. The continuous application of water-soluble potassic fertilizers [12] would have increased the concentration of K in soil solution with the increase in the rate of K application [13].

Table 2. Effect of different levels of potassium on water soluble and Exchangeable K (ppm) at different stages of maize

DAI/ Treatments	Water-soluble K									Exchangeable K								
	Vegetative			Tasseling			Harvest			Vegetative			Tasseling			Harvest		
	S_1	S_2	Mean	S_1	S_2	Mean	S_1	S_2	Mean	S_1	S_2	Mean	S_1	S_2	Mean	S_1	S_2	Mean
T_1 – Control	10.3	17.1	13.7	8.90	14.6	11.8	6.25	10.4	8.30	341	362	352	330	359	345	321	346	333
T_2 – 40 kg K_2O ha^{-1}	11.3	17.5	14.4	10.1	15.3	12.7	7.42	11.3	9.40	356	370	363	342	366	354	337	358	348
T_3– 80 kg K_2O ha^{-1}	12.2	17.8	15.0	10.9	15.8	13.3	8.36	11.7	10.0	362	375	368	352	371	362	348	366	357
T_4– 120 kg K_2O ha^{-1}	12.6	18.1	15.4	11.2	16.0	13.6	8.77	12.1	10.4	366	378	372	356	374	365	352	370	361
Mean	11.6	17.6	14.6	10.3	15.4	12.9	7.71	11.4	9.50	356	371	364	345	367	356	340	360	350
	S	T	S X T	S	T	S X T	S	T	S X T	S	T	S X T	S	T	S X T	S	T	S X T
SEd	0.15	0.21	0.30	0.17	0.24	0.33	0.09	0.14	0.19	2.94	4.16	5.88	3.00	4.25	6.01	3.54	5.00	7.08
CD (P=0.05)	0.32	0.45	NS	0.35	0.50	NS	0.20	0.29	NS	6.24	8.82	NS	6.37	9.01	NS	7.50	10.6	NS

Table 3. Effect of different levels of potassium on HNO_3 soluble and Non-Exchangeable K (ppm) at different stages of maize

DAI/ Treatments	HNO_3 soluble K									Non- Exchangeable K								
	Vegetative			Tasseling			Harvest			Vegetative			Tasseling			Harvest		
	S_1	S_2	Mean	S_1	S_2	Mean	S_1	S_2	Mean	S_1	S_2	Mean	S_1	S_2	Mean	S_1	S_2	Mean
T_1 – Control	732	864	798	667	815	741	648	795	721	391	501	446	337	457	397	327	449	388
T_2 – 40 kg K_2O ha^{-1}	754	884	819	704	833	769	684	814	749	398	514	456	362	468	415	347	456	402
T_3– 80 kg K_2O ha^{-1}	773	901	837	732	850	791	706	830	768	411	526	469	379	478	429	358	465	411
T_4– 120 kg K_2O ha^{-1}	783	912	847	748	864	806	717	841	779	417	534	475	392	491	441	365	472	418
Mean	760	890	825	713	841	777	689	820	754	404	519	462	367	473	420	349	460	405
	S	T	S X T	S	T	S X T	S	T	S X T	S	T	S X T	S	T	S X T	S	T	S X T
SEd	6.56	9.28	13.1	7.17	10.1	14.33	8.21	11.6	16.4	4.00	5.66	8.01	4.64	6.57	9.28	4.16	5.88	8.31
CD (P=0.05)	13.9	19.6	NS	15.1	21.4	NS	17.4	24.6	NS	8.49	12.0	NS	9.84	13.9	NS	8.81	12.4	NS

Table 4. Correlation among K fractions, stover and grain yield of maize in black soil

K fractions	Calcareous soil (S_1)		Non- calcareous soil (S_2)	
	Grain yield (g plant^{-1})	Stover yield (g plant^{-1})	Grain yield (g plant^{-1})	Stover yield (g plant^{-1})
HNO_3 soluble K (mg kg^{-1})	0.895**	0.880**	0.517**	0.478*
Non- exchangeable K (mg kg^{-1})	0.854**	0.836**	0.281*	0.448**
Exchangeable K (mg kg^{-1})	0.775**	0.748**	0.372**	0.529*
Water soluble K (mg kg^{-1})	0.917**	0.902**	0.734**	0.786**

3.2 Exchangeable-K

In both the soil types (S_1 and S_2), K application has increased the exchangeable -K content over control at all the stages of crop growth. The exchangeable K content showed continuous reduction from vegetative, tasseling and harvest stages of maize with a mean varied from 352 to 372 ppm at vegetative, 345 to 365 ppm at tasseling and 333 to 361 ppm at harvest stages, respectively (Table 2). Application of 120 kg K_2O ha^{-1} registered the higher amount of exchangeable K at vegetative (366 and 378 ppm), tasseling (356 and 374 ppm) and harvest stages (352 and 370 ppm) of maize in calcareous soil (S_1) and non- calcareous soil (S_2). Application of potassium @ 120 kg K_2O ha^{-1} is necessary to get higher exchangeable K in calcareous soil whereas in non calcareous soil (S2), application of potassium @ 80 kg K_2O ha^{-1} showed on par effect with each other (Table 2). This is due to shift in equilibrium by addition of water soluble K sources in both the soil types [14]. As in case of water-soluble K, withholding K from schedule resulted in a reduction in exchangeable K content [13].

3.3 HNO_3 Soluble K

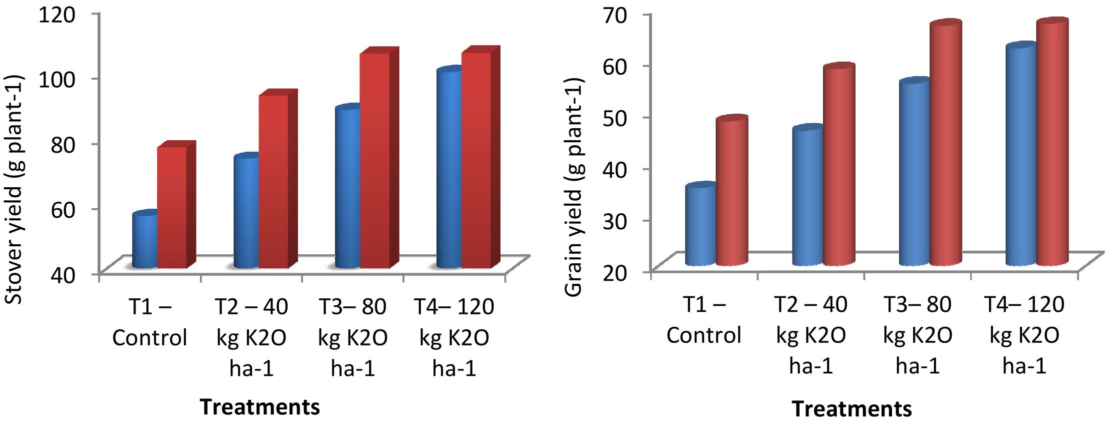
Among all the K fractions investigated, HNO_3 K fraction constitutes about more than 80 % of the total K in soils (S_1 and S_2) with mean value ranged from 732 to 783 and 864 to 912 ppm (vegetative), 667 to 748 and 815 to 864 ppm (tasseling) and 648 to 717 and 795 to 841 ppm (harvest) in calcareous and non- calcareous soil, respectively. The mean values varied from 798 to 847 in vegetative stage, 741 to 806 ppm at tasseling, 721 to 779 ppm at harvest stage, respectively (Table 3). The amount of lattice K mainly depends on clay mineralogical composition of soil rather than the dynamics among different K pools. The lower amount of lattice K in the absence of K fertilization slower shift in equilibrium to compensate crop removal and to translocation of clays as reported [15]. Among all the extractants, significantly higher amounts of K were extracted by 1 *N* HNO_3 because in addition to exchangeable K, some of the non-exchangeable K is brought into solution by the breakdown of primary and secondary clay minerals. The mineral acids release more K than organic acids since mineral acids add higher H^+ activity for the same concentration and are obviously more effective in solubilizing K from minerals [16].

3.4 Non-Exchangeable-K (NEK)

The data indicated that maximum non-exchangeable K content values were observed with the application of potassium @ 120 kg K_2O ha^{-1} treatment at all the stages of crop sequence in calcareous soil (S_1) which was on par with potassium @ 80 kg K_2O ha^{-1} in non- calcareous soil. The non-exchangeable K values were 391 to 417 and 501 to 534 ppm, 337 to 392 and 457 to 491 ppm, 327 to 365 ppm and 449 to 472 ppm at vegetative, tasseling and harvest of maize in calcareous soil and non-calcareous soil, respectively (Table 3). It indicated that with the increase in native lime levels, the non-exchangeable K content decreased significantly. The higher status of non-exchangeable K in some soil series might be due to higher pedo-chemical weathering of K bearing minerals in soil and transformation into illite and vermiculite [1]. It indicated that non-exchangeable K was released and contributed partially to the soil [17].

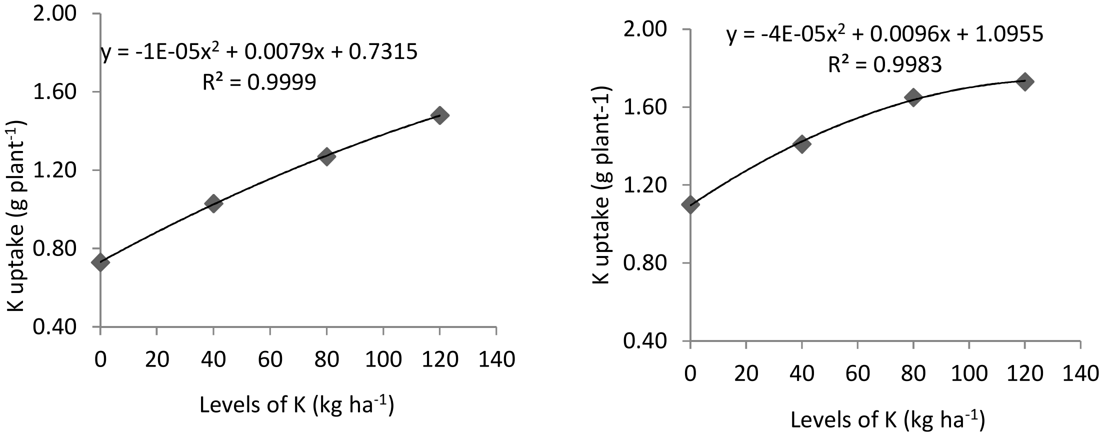
3.5 Stover and Grain Yield

The economic biomass in terms of grain yield and stover yield of hybrid maize increased significantly by the application of different levels of potassium. The grain and stover yield varied from 35.0 to 62.2 g $plant^{-1}$ and 56.0 to 73.6 g $plant^{-1}$ in calcareous soil (S_1), whereas in non-calcareous soil (S_2), it ranged from 48.0 to 66.9 g $plant^{-1}$ and 77.1 to 106 g $plant^{-1}$, respectively (Fig. 1). Progressive increase in grain yield and stover yield was observed with application of graded levels of K addition from 40 kg K_2O to 120 kg K_2O in calcareous and non-calcareous soil (Fig. 1). The straw yield of hybrid maize followed similar trend to that of grain yield. Therefore, the availability of K during initial stage to until the end of grain filling increases the filled grain number in cob and grain weight, as observed in these studies. Increasing in stover yield may be attributed to increase in plant height and dry matter production [18]. The positive effect of K on crop yield might also be due to its requirement in carbohydrate synthesis and translocation of photosynthesis and also may be due to improved yield attributing characters, shoot growth and nodulation [4]. Application of potassium as found to increase the shoot dry weight of maize may be due to selective an adequate potassium uptake in plant tissue. This yield increase was mainly due to significant improvement in the yield attributes due to balanced supply of nutrients. Similar findings were also reported [2], [19], [20].



Calcareous soil (S_1) **Non – Calcareous soil (S_2)**

Fig. 1. Effect of different levels of potassium on stover and grain yield of maize in black soil



Calcareous soil (S_1) **Non – Calcareous soil (S_2)**

Fig. 2. Effect of different levels of potassium on K uptake in black soil

3.6 Potassium Uptake

The K content in grain and stover of maize increased progressively and significantly with increased K application rates. The result indicated a marked variation in the K uptake by hybrid maize due to the variation in fertilizer treatments imposed in both the soils. Maximum total K uptake (1.48 and 1.73 g plant^{-1}) as recorded with the treatment receiving 120 kg K_2O ha^{-1} in calcareous and non- calcareous soils, respectively which differed significantly when compared to all other treatments. In calcareous soil, potassium @ 120 kg ha^{-1} is necessary for higher K uptake whereas in non- calcareous soil, potassium @ 80 kg ha^{-1}it showed on par effect with application of 120 kg K_2O ha^{-1} (Fig. 2). In general, the K uptake was increased with crop growth and maturity of the crop [20]. The highest total k uptake was due to higher available K status and high cation exchange capacity in the initial soil. Plants deficient in potassium will not produce proteins despite an abundance of available nitrogen. Instead, incomplete proteins such as amino acids, amides and nitrates will accumulate in the cell. This is because of the enzyme nitrate reductase, which catalyzes the formation of proteins, is activated by potassium [21]. Similar to the present study on maize crop, increase in uptake due to increased levels of potassium was noticed [22], which was attributed to translocation of nutrients by applied K which plays a role in increasing nutrients uptake by plants. Potassium has a synergetic effect on uptake of nitrogen and other nutrients due to which all the treatments applied with potassium was superior to control [23], [4].

3.7 Relationship between K Fractions, Crop Yield and Nutrient Uptake

A significant and positive correlation was existing between all fractions of potassium viz., HNO_3 soluble K, non- exchangeable K, Exchangeable K and water-soluble K with grain and stover yield in calcareous soil (S_1) and non- calcareous soil (S_2). Calcareous soil showed comparatively better response to the application of potassium especially in water soluble K with an R^2 value of 0.917** followed by HNO_3 soluble K with an R^2 value of 0.895** (Table 4). Increase in uptake of K with increase in levels of K application on calcareous and non- calcareous soils in the present studies implies that inadequate supply or absence of any one major nutrient to the crop would result in imbalance supply of other nutrient elements and consequent reduction in yield, nutrient use efficiency and uptake [24]. All the forms of K showed a positive trend of correlation among themselves largely corroborating the well-known concept of existence of a dynamic equilibrium among different forms of K present in soil through which K supply to the roots of crop plants are directly or indirectly ensured. Similar results were also reported [25], [16] by which provide credence to the results obtained in the study.

4. CONCLUSIONS

The results indicated that the amount of K extracted by different extractants was more in non- calcareous soil followed by calcareous soil. Significant higher available K in calcareous soil with the application of enhanced K application (120 kg K_2O ha^{-1}) was observed and the effect was on par with the application of lesser K application (80 kg K_2O ha^{-1}) in non-calcareous soil. Higher levels of application of K led to higher values of K fractions during of crop growth stages, emphasizing the importance of potassium to calcareous soil. Similarly, significantly higher grain and straw yield of hybrid maize recorded at higher level of K (120 kg K_2O ha^{-1}) in calcareous soil than slightly lower level of K (80 kg K_2O ha^{-1}) to non-calcareous soil. Also, there is a significant and positive correlation was existing between fractions of potassium with grain and stover yield. The present investigation concludes that there is a vital importance for inclusion of higher dose of potassium in calcareous soil for maintaining soil K dynamics and enhancing yield of hybrid maize and sustain soil productivity.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Annapurna MV, Kadam BS, Surabhi HK. Distribution of different forms of potassium of representative soil series of sub-montane zone of Maharashtra, India. International Journal of Current Microbiology and Applied Science. 2017;6(7):2648-2653.
2. Sarkar GK, Debnath A, Chattopadhyay AP, Sanyal SK. Depletion of soil potassium under exhaustive cropping in Inceptisols and Alfisols. Communication on Soil Science and Plant Analysis. 2014;45:61-72.
3. Mengel K, Kirkby EA. Research on potassium in agriculture: needs and prospects. Kluwer acad. Publishers. Plant and Soil. 2001;335(1-2):155-180.
4. Chaudhari AV, Mane SS, Chadar BR. Effect of graded levels of potassium on growth, yield and quality of black gram. International Journal of Current Microbiology and Applied Science. 2018;6: 1607-1612.
5. Lalitha M, Dhakshinamoorthy M. Forms of soil Potassium – A Review. Agri. Reviews. 2014: 35(1):64-68.
6. Ramamoorthy B, Velayutham M. Nitrogen, phosphorus and potassium in soils: Chemistry, forms and availability. In Soil Fertility – Theory and Practice (J.S. Kanwar, Ed.), Indian Council of Agricultural Research, New Delhi. 1976;156-201.
7. Sen U, Ghosh AK. Changes in potassium forms, clay and silt mineralogy brought about by intensive cropping. Clay Research. 2011;30:29-41.
8. Ravichandran M, Srirama Chandra Sekharan MV. Optimizing timing of potassium application in productivity enhancement of crops. Karnataka Journal of Agricultural Science. 2011;24:75-80.
9. M. C. LEAN, A. E. M. Intracellular potassium in dietary liver necrosis. Nature, London. 1960;185: 936-937.
10. Hanway JJ, Heidel H. Soil analyses methods as used in Iowa state college soil testing laboratory, Iowa Agriculture. 1952;57:1–31.

11. Wood LK, De turk EE. The adsorption of potassium in soil in non replaceable form. Soil Science Society and American Proceedings. 1941;5:152-161.
12. Afroz D, Abedin Mian MJ, Hossain MA, Rashid ES. Effects of split application of potassium on yield and potassium balance for boro rice (BRRI dhan 29). International Journal of Biological Research. 2009;7:73-79.
13. Rout PP, Chandrasekaran N, Arulmozhiselvan S. Effect of Long Term Fertilization on Soil K dynamics and uptake by Hybrid Maize in an Irrigated Inceptisol under Intensive Cropping. International Journal of Current Microbiology and Applied Science. 2017;6(10):1049-1061.
14. Thippeswamy HM, Shivakumar BG, Balloli SS. Potassium transformation studies in lowland rice (O. sativa L.) as influenced by levels and time of K application. Journal of Potassium Research. 2000;16:7-11.
15. Das K, Singh SK, Shyampura RL. Forms of potassium in relation to land form and soil properties of Basaltic Terrain. Journal of Indian Society of Soil Science. 1993: 41(2): 557-559.
16. Kalyani K, Sailaja V. Rao CP. Potassium Fractions in Soil and Response of Cauliflower (Brassica oleraceavar. Botrytis) in Coarse Textured Soils of Rangareddy District. Journal of Indian Society of Soil Science. 2015;63(1): 69-74.
17. Bansal SK, Trehan SP. Effect of potassium on yield and processing quality attributes of potato. Karnataka Journal of. Agricultural. Science. 2011;24(1):48-54.
18. Swetha P, Solanki D, Kumari S, Savalia SG. Effect of potassium and sulphur on yield and yield attributes of pop corn (Zea mays Var. Everta). International Journal of Current Microbiology and Applied Science. 2017; 6(8):646-655.
19. Balyan JK, Singh P, Kumpawat BS, Jain LK. Effect of integrated nutrient management on maize (Zea mays L.) growth and its nutrients uptake. Current agriculture. 2006;30(1-2):79-82.
20. Paramasivan M, Kumaresan KR, Malarvizhi P, Mahimairaja S, Velayudham K. Effect of different levels of NPK and Zn on yield and nutrient uptake of hybrid maize (COHM 5) (*Zea mays* L.) in Mayamankuruchi (Myk) series of soils of Tamil Nadu. An Asian Journal of Soil Science. 2010: (5)1:157-161.
21. Ujwala Ranade M. Interaction of micronutrients with major nutrients with special reference to potassium. Karnataka Journal of Agricultural Science. 2011;24(1):106-109.
22. Sanjeev Kumar, Shivadhar, Ashok Kumar., Dileep Kumar. Yield and nutrient uptake of maize (Zea mays)–wheat (*Triticum aestivum*) cropping system as influenced by integrated potassium management. Indian Journal of Agronomy. 2015;60(4):511-515.
23. Patil S, Basavaraja PK, Parama VRR, Chikkaramappa, Sheshadri T. Effect of Different Sources and Levels of K on Maize (Zea mays L.) Yield, Nutrient Content and Uptake by Maize Crop in Low K Soils of Eastern Dry Zone of Karnataka, India. International Journal of Current Microbiology and Applied Science. 2017;6(8):577-587.
24. Anonymous. Annual progress report. AICRP on Long Term Fertilizer Experiments to study the changes in soil quality, crop productivity and sustainability. IISS, Bhopal; 2006.
25. Lungmunana Bose A., Ghosh I, Ghosh SK, Patra PK. Distribution and variation of potassium in rice growing soils of red and laterite zone of West Bengal. Journal of Indian Society of Soil Science. 2014;62(1):84-87.

Peer-review history:
The peer review history for this paper can be accessed here:
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