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RESEARCH ARTICLE

Effect of Potassium on Growth, Yield and NPK Uptake of Hybrid Maize in Black Calcareous Soil

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ABSTRACT

Potassium is one of the major nutritive element which will require greater attention in order to ensure grain yield and mitigation of biotic and abiotic stresses as well as improvement in quality of maize. The soils with high in calcium and or magnesium may require high levels of K for satisfactory nutrition of crops. The availability of K depends on concentration relative to that of Ca^{2+} and Mg^{2+} than on the total quantity of K present. To study the influence of potassium levels and its influence on growth, yield and nutrient uptake in maize, a pot culture experiment was carried out with graded levels of potassium (T_1 – control, T_2 – 40 kg K_2O ha^{-1}, T_3 – 80 kg K_2O ha^{-1}, T_4 -120 kg K_2O ha^{-1}) to study the influence of potassium on growth, yield and nutrient uptake of maize in calcareous soil. The results indicated that plant height showed significant response up to 40 kg K_2O ha^{-1}, whereas SPAD values and Leaf area index were higher up to 80 kg K_2O ha^{-1} while the root parameters showed significant response up to 120 kg K_2O ha^{-1}.Yield parameters *viz*., cob length and 100 grain weight were significantly influenced up to 120 kg K_2O ha^{-1}. Whereas, cob girth and rows per cob responded only up to 80 kg K_2O ha^{-1}. Grain and stover yield of hybrid maize showed significant response up to 120 kg K_2O ha^{-1}. The total uptake of N, P and K showed significant response up to 120 kg ha^{-1} in calcareous soil. Significant positive correlation occurs between growth, yield parameters, NPK uptake. Application of potassium up to 120 kg K_2O ha^{-1} is necessary for the continuous supply of K to maize and to maintain K equilibrium in soil.

Keywords: *Grain yield, Hybrid Maize, Inceptisols, NPK Uptake, Potassium.*

Potassium comprise on an average 2.6 per cent of the earth crust, making it the seventh most abundant element and fourth most abundant mineral nutrient in the lithosphere. Out of this total K content, 98 per cent is bound in the mineral form, whereas two per cent is in soil solution and exchangeable phases (Bertsch and Thomas, 1985). It is comparatively higher than any other essential plant nutrient in soil. Cereal crops require more, potash than any other nutrient including nitrogen.

Optimum ionic balance of nutrients in the root environment is a prerequisite for balanced nutrition of crops. Occurrence of deficiency symptoms of calcium, magnesium and potassium on plant parts has warranted the scientists to consider the effects of these cations in the soil solution on the uptake of one another. It is therefore important to establish whether the supply of one of these cations is decreased by ionic antagonisms to such an extent that growth and yield are depressed (Ansari, 2010). The free lime content ($CaCO_3$) of black calcareous soils of Coimbatore district varies from 10 to 15 percent. The present study was planned to elucidate the changes in growth, yield parameters and yield of maize as influenced by graded levels of potassium in calcareous soil.

MATERIAL AND METHODS

A pot culture experiment was conducted during 2017- 2018 in Department of SS & AC TNAU, Coimbatore. Calcareous soil was collected from Eastern block, TNAU Coimbatore at 11°12' North latitude and 77°03' East longitude and it belongs to Periayanaickenpalayam series, taxonomically referred as sandy clay loam, mixed black calcareous, Vertic Ustropept. The initial soil fertility was found to be medium in organic carbon (5.25 g kg^{-1}), available N (135 kg ha^{-1}), available P (14 kg ha^{-1}) and high in available K (736 kg ha^{-1}). There were four treatments each replicated thrice in Completely Randomized Block Design. Based on STCR recommendation,

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the recommended dose of N, P_2O_5 and graded levels of K were given. 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). 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). In each pot, one plant was maintained at required level of soil moisture.

Fertilizer prescription equations for maize

$$FN = 4.01\,T - 0.76\,SN - 0.83\,ON$$

$$FP_2O_5 = 1.57\,T - 2.71\,SP - 0.61\,OP$$

$$FK_2O = 2.09\,T - 0.26\,SK - 0.65\,OK$$

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 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.

At maturity, plant height was measured from the base of the plant to the tip of the top leaf and it was expressed in cm. Physiological parameters *viz.*, Leaf area index was worked out using the formula (LAI= Leaf area per plant (cm^2) / Ground area covered by plant (cm^2)), SPAD readings were recorded using Chlorophyll Meter (SPAD 502) designed by the Soil Plant Analytical Development (SPAD) section, Minolta, Japan. Leaf gas exchange measurement were performed using Portable Photosynthesis System (PPS) (Model LI-6400 of LICOR inc., Lincoln, Nebraska, USA) equipped with a halogen lamp (6400- 02B LED) and the readings were expressed in µmol CO_2 $m^{-2}s^{-1}$

Grain and stover yield at harvest was recorded after drying. Nitrogen, phosphorus and potassium nutrient content were analyzed using standard procedures i.e., nitrogen concentration using Kjeldahl's digestion-distillation method (Piper, 1966), phosphorus by vanadomolybdophosphoric yellow color method (Jackson, 1973) and potassium using flame photometer (Piper, 1966). The uptake of nutrients by hybrid maize was worked out by multiplying the content with dry matter production and expressed in g $plant^{-1}$.

The data were subjected to the analysis of variance (ANOVA) and correlation statistics to find out the magnitude of treatment effect on various parameters and also to establish possible relationship among soil and plant performance. For statistical analysis of data, Microsoft Excel (Microsoft Corporation, USA) and Agres window version 7.0 packages were used.

RESULTS AND DISCUSSION

Growth parameters

Plant height

The plant height of maize was influenced significantly by the application of graded levels of potassium in black calcareous soil. Application of potassium @ 120 kg ha^{-1} (T_4) recorded the highest plant height of 119.5 cm and was found to be on par with potassium @ 80 kg ha^{-1} (T_3) (117.8 cm) and potassium @ 40 kg ha^{-1} (T_2) (114.7 cm) (Table 1). Improvement in growth parameters with potassium application might be due to delayed leaf senescence, sustained leaf photosynthesis and better vegetative growth (Swetha *et al.,* 2017). Throughout the crop growth period, the plant under graded level of potassic fertilizers performed better when compared to control. The significant and positive correlation between nitric acid soluble K, water soluble K, non- exchangeable K and available K (R^2=0.873**, 0.741**, 0.735** and 0.728**) (Table 2).

Root parameters

The root length, root volume and root weight of maize was significantly influenced by the soil application of graded levels of potassium. Application of potassium @ 120 kg ha^{-1} (T_4) recorded the highest root length; root volume and root weight (Table 1). While phosphorus is well known for promoting early root formation and growth, potassium may have an even greater effect on root development. Cereals have two root systems: seminal roots that develop initially from the seed, and nodal roots which develop from the crown level to support tillers (www.ppi-ppic.org/agri-briefs). Application of K in the soil increases plant bio mass, length density and root diameter of upland rice cultivars. Differences in root length were found as a function of K fertilization, type of plant and contributed for the improvement in root parameters. It is proved that significant and positive correlation was existing between water soluble K, nitric acid soluble K, non- exchangeable K, exchangeable K and available K with root length (R^2=0.931**, 0.855**, 0.0.845**, 0.823** and 0.750**), with root volume (R^2= 0.905**, 0.852**, 0.804**, 0.790* and 0.758*) and root weight (R^2= 0.918**, 0.876**, 0.817**, 0.783** and 0.768**) respectively which could have maintained the constant K supply (Table 2).

Table 1. Effect of different levels of potassium on growth, physiological parameters, yield attributes and NPK uptake of hybrid maize

Treatments	Growth parameters				Physiological parameters			Yield characters				Yield (g plant^{-1})		Uptake (g plant^{-1})		
	Plant height (cm)	Root length (cm)	Root volume (cc)	Root weight (g)	SPAD value	LAI	Photosynthetic rate (µ mol CO_2 m^{-2} s^{-1})	Cob length (cm)	Cob girth (cm)	Rows per cob	100 grain weight (g)	Stover yield	Grain yield	N	P	K
T_1– Control	109.2	32.5	18.0	4.9	27.0	3.10	20.2	8.8	5.2	6.7	9.8	56.0	35.0	0.98	0.11	0.73
T_2- 40 kg K_2O ha^{-1}	114.7	38.7	22.3	7.0	28.0	3.38	26.1	11.0	6.2	7.7	13.0	73.6	46.2	1.45	0.17	1.03
T_3- 80 kg K_2O ha^{-1}	117.8	43.8	24.2	8.4	29.0	3.50	30.0	13.0	7.0	8.3	15.5	88.6	55.3	1.90	0.21	1.27
T_4- 120 kg K_2O ha^{-1}	119.5	46.9	25.8	9.3	30.0	3.58	31.8	13.6	7.3	8.7	17.6	100.2	62.2	2.22	0.25	1.48
S Ed	2.26	0.83	0.40	0.15	0.50	0.07	0.38	0.16	0.13	0.19	0.21	1.71	1.52	0.04	0.01	0.02
CD (P=0.05)	5.22	1.90	0.91	0.35	1.15	0.16	0.88	0.38	0.30	0.43	0.48	3.94	3.50	0.09	0.01	0.05

Physiological parameters

SPAD values

The SPAD values are related to chlorophyll content of the crop. Application of potassium @ 120 kg ha^{-1} (T_4) with the SPAD value of 30.0 was found to be on par with potassium @ 80 kg ha^{-1} (T_3) (29.0) (Table 1). Absolute control recorded the lowest SPAD values in all the growth stages. Significant relationship between SPAD values and chlorophyll content has been reported by Martínez and Guiamet (2004). Viana *et al.* (2010) reported that the chlorophyll index increased after addition of nitrogen and potassium. Adequate supply of K is essential to maintain the availability of nitrogen to maize. Significant and positive correlation between exchangeable K and water soluble K with SPAD values (R^2= 0.696** and 0.716**) indicated the role of K in supply of other nutrients to maize (Table 2).

Leaf area index

The leaves of a plant are normally its main organ of photosynthesis and the total area of leaves per unit ground area, called leaf area index (LAI) is an important biophysical descriptor of crop canopies. Application of potassium @ 120 kg ha^{-1} (T_4) recorded the highest LAI (3.58) and found to be on par with potassium @ 80 kg ha^{-1} (T_3) (3.50) (Table 1). Application of K enhanced leaf growth and maintained cell osmotic potential (Aslam *et al.*, 2013). Increasing potassium levels could have increased the amount of cellular constituents, mainly protoplasm resulting in increased LAI, which increased the leaf area. Application of increasing levels of NPK at all growth stages of maize increased the Leaf Area Index of the sweet corn (Rao and Padmaja, 1994). Significant and positive correlation was observed between nitric acid soluble K, water soluble K, non- exchangeable K and exchangeable K with LAI (R^2= 0.756*, 0.715*, 0.702* and 0.635*) (Table 2).

Photosynthetic rate

Application of potassium @ 120 kg ha^{-1} (T_4) recorded the highest photosynthetic rate of 31.0 µ mol CO_2 m^{-2} s^{-1} (Table 1). Potassium influences the process of photosynthesis, namely synthesis of ATP, activation of the enzymes involved in photosynthesis, CO_2 uptake, balance of the electric charges required for photophosphorylation in chloroplasts and acting as the counter ion to light-induced H^+ flux across the thylakoid membranes. Results confirm that K fractions *viz*., water soluble K, nitric acid soluble K, available K, exchangeable K, and non-exchangeable K exerted significant and positive correlation with photosynthetic rate (R^2= 0.934**, 0.864**, 0.837**, 0.789* and 0.763*) (Table 2).

Yield attributes

Cob length and girth

Application of potassium @ 120 kg ha^{-1} (T_4) recorded the highest cob length of 13.6 cm in calcareous soil (Table 1). Among the various treatments, cob length was reduced in absolute control (T_1) which shows the necessity of potassic fertilisers for consistent supply of nutrients for yield components of maize. Swetha *et al.* (2017) also confirmed the essentiality of K fertiliser on cob length of maize. Increase in yield components with potash fertilization might be due to the role of potassium in increasing cell division, improved plant growth conditions in water use efficiency and also results in quick transportation towards grain (Marschner, 1995). The continuous filling of grains due to sufficient photosynthesis might have resulted in increased length and size of the cob. The results of the present study are in accordance with the findings of Srinivasa (2013). Application of potassium @ 120 kg ha^{-1} (T_4) with the cob girth of 7.3 cm was found to be on par with potassium @ 80 kg ha^{-1} (T_3) (7.0 cm) (Table 1). This may be due to continuous filling of grains with sufficient photosynthates that lead to increased size of cob and it resulted in increased cob girth. This finding was also supported by Srinivasa (2013). Higher cob diameter was also attributed to the supply of sufficient NPK nutrients essential for constituents of plant tissues involved in cell division and cell elongation (Gul *et al*., 2015).

Table 2. Correlation between various K fractions with growth, physiological parameters and NPK uptake of maize

K fractions	Growth parameters				Physiological parameters					Uptake		
	Plant height (cm)	Root length (cm)	Root volume (cc)	Root weight (cm)	SPAD values	Leaf Area Index	Photo synthetic rate	Yield (g plant^{-1}) Grain	Stover	Nitrogen	Phosphorus	Potassium
HNO_3 soluble K (mg kg^{-1})	0.873**	0.855**	0.852**	0.876**	0.566**	0.756**	0.864**	0.895**	0.880**	0.870**	0.838**	0.883**
Non- exchangeable K (mg kg^{-1})	0.735**	0.845**	0.804**	0.817**	0.614**	0.702*	0.763**	0.854**	0.836**	0.824**	0.806**	0.848**
Exchangeable K (mg kg^{-1})	0.550**	0.823**	0.758**	0.783**	0.696**	0.635**	0.789**	0.775**	0.748**	0.743**	0.799**	0.765**
Water soluble K (mg kg^{-1})	0.741**	0.931**	0.905**	0.918**	0.716**	0.715**	0.934**	0.917**	0.902**	0.901**	0.912**	0.905**
Available K (mg kg^{-1})	0.728**	0.750**	0.790**	0.768**	0.476**	0.547**	0.837**	0.802**	0.794**	0.813**	0.744**	0.768**

Rows per cob

Application of potassium @ 120 kg ha^{-1} (T_4) recorded the highest number of rows with 8.7 was found to be on par with potassium @ 80 kg ha^{-1} (T_3) (8.3) (Table 1). Increase in levels of potassic fertilizer concomitantly increased the number of rows per cob. More nutrient availability resulting in higher leaf area index might have resulted in higher availability of assimilates resulting in improved number of rows per cob (Gul *et al*., 2015).

Hundred grain weight

Application of potassium @ 120 kg ha^{-1} (T_4) recorded the highest 100 grain weight of 13.8 g in calcareous soil (Table 1). Increase in 100 grain weight relates to the enhanced source efficiency as well as sink capacity which indicated the enhanced translocation of assimilated food materials from source to sink. The potential weight of individual grain is determined by the number of endosperm cells, which is formed with in the first 2-3 weeks after pollination (i.e. before the start of linear grain growth stage. Potassium enhances activity of enzymes responsible for accumulation and translocation of carbohydrates from source to sink and resulted in heavier grains as documented by Aslam *et al*. (2013).

Grain yield

The grain yield of hybrid maize ranged from 35.0 to 62.2 g plant^{-1}.The maize grain yield was significantly influenced by the graded levels of potassium. Application of potassium @ 120 kg ha^{-1} (T_4) (62.2 g plant^{-1}) recorded the highest grain yield of maize in calcareous soil (Table 1). Such a yield increase might be due to the prolific root growth, enhanced water and nutrient absorption. The increase in yield was due to increase in availability, absorption and translocation of potassium nutrient from soil to plant (Ramachandrappa, 2013). This clearly emphasized the need for K addition for maintaining soil productivity. A significant and positive correlation was noticed between K fractions (water soluble, nitric acid soluble K, non- exchangeable K, available K and exchangeable K) and grain yield (R^2= 0.917**, 0.895, 0.854**, 0.802**, 0.775*) (Table 2).

Stover yield

The stover yield of hybrid maize followed the similar trend to that of grain yield. The highest stover yield was recorded with the application of potassium @120 kg K_2O ha^{-1} (100.2 g plant$^{-1)}$ in calcareous soil (Table 1).

Increasing in stover yield may be attributed to increase in plant height, number of leaves and dry matter production. Increase in dry matter production with increased fertilizer application might be due to the combined role of NPK with their enhanced use efficiency (Wadsworth, 2002). Application of potassium was found to increase the shoot dry weight of maize due to selective and adequate potassium uptake in the plant tissue (Kaya *et al*., 2009). Results could be supported by the significant and positive correlation between K fractions (water soluble, nitric acid soluble K, exchangeable K, available K and non-exchangeable K) and stover yield (R^2= 0.902**, 0.880**, 0.748*, 0.794**, 0.836**) (Table 2).

Nitrogen uptake

Application of potassium @ 120 kg ha^{-1} (T_4) recorded the highest total nitrogen uptake of (2.22 g plant^{-1}) (Table 1). This might be due to improved utilization of applied nitrogen in the presence of sufficient potassium. Similar positive interaction between N and K was also reported by Thippeswamy (1995) who reported that the content and uptake of N and K was found to increase significantly with the levels and split application of K in ragi. Increased uptake of nitrogen might have resulted in vigorous growth and higher photosynthetic rate which led to better uptake of N throughout the crop growth period. The results were supported by the significant and positive correlation between water soluble K, nitric acid soluble K, non- exchangeable K, exchangeable K and available K with total nitrogen uptake (R^2=0.901**, 0.870**, 0.824**, 0.743*, 0.813**) (Table 2).

Phosphorus uptake

Uptake of nutrient is a product of biomass accumulated by particular part and its nutrient content. In maize crop, application of potassium @ 120 kg ha^{-1} (T_4) recorded the highest phosphorus uptake of 0.25 g $plant^{-1}$ (Table 1).This might be due to availability of sufficient potassium at different stages of crop growth which favoured the better root growth and dry matter production resulting in increased content and uptake of phosphorus.Kumawat (2014) observed that application of potassium increases the uptake in plant. Similar positive interaction between P and K was also reported by Srinivasa (2013). With increase in levels of potassium application, there was an increase in uptake of other nutrients viz., nitrogen and phosphorus due to synergistic influence and translocation of other nutrients by the applied potassium (Kumar *et al*., 2015).The results were supported by significant and positive correlation between water soluble K, nitric acid soluble K, available K, non- exchangeable K and exchangeable K with total P uptake (R^2= 0.912**, 0.838**, 0.744*, 0.806** and 0.799**) respectively (Table 2).

Potassium uptake

The result on K uptake by hybrid maize indicated a marked variation in the K uptake due to variation in the treatments imposed. Potassium @ 120 kg ha^{-1} (T_4) recorded the highest potassium uptake of 1.48 g $plant^{-1}$ (Table 1). Increase in the uptake of potassium by maize may be ascribed to more availability of potassium at critical stages from the added fertilizer sources and native soil potassium. This is in conformity with the findings of Srinivasa (2013) and Thippeswamy (1995). The concentration of cation in most plant tissues is a function of crop and fairly independent of the soil or fertilisation; even though dry soil condition severely reduce the mobile ions to roots which impede transformation of soil, nutrients to plant- available form (Hussaini *et al*., 2008). Increasing rooting depth might have increased K uptake since diffusion to root surface is the primary mechanism responsible for potassium uptake (Barber, 1984).The significant and positive correlation was observed with water soluble K, nitric acid soluble K, non- exchangeable K, exchangeable K and available K with total potassium uptake (R^2=0.905**, 0.883**, 0.848**, 0.765**, 0.768**) (Table 2).

CONCLUSION

The experimental results can be indicated that, application of potassium @ 40 kg K_2O ha^{-1} increased the plant height of maize. Physiological parameters like SPAD value, Leaf area index and yield attributes like cob girth and rows per cob were responded up to potassium @ 80 kg K_2O ha^{-1} but photosynthetic rate responded up to potassium @ 120 kg K_2O ha^{-1}. 100 grain weight, cob length, grain yield, stover yield and nutrient uptake of NPK were higher by the application of potassium @ 120 kg K_2O ha^{-1}. In calcareous soil, consistent supply of K is necessary to maintain not only K but also other nutrients to increase crop biomass, yield parameters and grain yield of maize. The study proved that consistent supply of potassium to maize enhances growth, physiological parameters and nutrient uptake which resulted higher grain and stover yield of maize.

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