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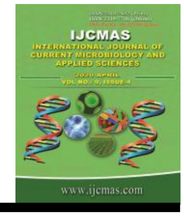

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# Influence of Graded Levels on Potassium on Physiological Parameters of Hybrid Maize in Inceptisol

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**A B S T R A C T**

Agricultural production continues to be constrained by a number of biotic and abiotic factors that can reduce crop yield quantity and quality. Potassium (K) is an essential nutrient that affects most of the physiological processes that influence plant growth. To understand the effect of potassium, a pot culture experiment was carried out with graded levels of potassium to study the influence of potassium on physiological parameters of maize in black calcareous and non-calcareous soils. Results indicated that Leaf area index, photosynthetic rate and stomatal conductance were significantly influenced up to 120 kg $K_2O$ $ha^{-1}$ in calcareous soil, whereas SPAD values were significantly influenced up to 80 kg $K_2O$ $ha^{-1}$. In non-calcareous soil, SPAD values, Leaf Area Index and stomatal conductance were significantly enhanced upto 80 kg $K_2O$ $ha^{-1}$ while photosynthetic rate increased up to 120 kg $K_2O$ $ha^{-1}$. Hence, to increase the physiological activity of hybrid maize, potassium @ 120 kg $K_2O$ $ha^{-1}$ is necessary for black calcareous soil and 80 kg $K_2O$ $ha^{-1}$ required for black non-calcareous soils in Inceptisol. Grain and straw yield of maize was positively correlated with physiological parameters like leaf area index and photosynthetic rate in calcareous soil and photosynthetic rate and stomatal conductance in non-calcareous soil. Balanced fertilization and efficient K usage in combination with other nutrients not only contribute to sustainable crop's growth, yield and quality, but also influence plant health and reduce the environmental risks.

## Introduction

Maize is the third most important food grain in India after wheat and rice with an area of 9, 63,320 ha and production of 25.89 million tons and the productivity of 2689 kg $ha^{-1.}$ In Tamil Nadu, maize cultivated in an area of 31,503 ha with the production of 0.95 million tonnes (Indiastat, 2017). Potassium supply affects a wide range of physiological processes in higher plants. Potassium (K) is one of important nutrient elements in crop growth, which modifies dozens of enzyme activations and controls stomatal movement of photosynthesis (Romheld and Kirkby, 2010). Plants absorb K in larger amounts than any other mineral element (except for nitrogen), and K is the nutrient that most frequently limits plant growth and crop yields.

The K cation has no structural purpose, but is the most common cation in plant biochemical processes, acting as an activator or cofactor in several enzyme systems. Potassium influences the process of photosynthesis at many levels, namely synthesis of ATP, activation of the enzymes involved in photosynthesis, $CO_2$ uptake, and 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 (Marschner, 1995).

Therefore, plants that have adequate K nutrition will be able to withstand longer periods of low soil moisture and increase the efficiency of physiological activity.

## 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.

Two soils were taken for the experiments.. The calcareous soil was taken from Eastern block, TNAU Coimbatore at 11º12' North latitude and 77º03' East longitude and it belongs to Periayanaickenpalayam series, taxonomically referred as sandy clay loam, mixed black calcareous, Vertic Ustropept and the non- calcareous soil was collected from farmers field of Ikkarai Boluvampatti village, Thondamuthur block, Coimbatore district of Tamil Nadu at 10.96256º North latitude and 76.79183° East longitude at an altitude of 315 m above mean sea level.

## Treatment details

The experiment was laid out with four treatments each replicated thrice. Based on STCR recommendation, 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 $K_2O$ $ha^{-1}$ ($T_4$). 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** |
| **$FP_2O_5$** | **1.57 T- 2.71 SP - 0.61** |
| **$FK_2O$** | **2.09 T- 0.26 SK - 0.65** |

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.

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. By using Portable Photosynthesis System (PPS) meter, Photosynthetic rate and Stomatal conductance measurements were taken and the readings were expressed in μ mol $CO_2$ $m^{-2}$ $s^{-1}$ and m mol $m^{-2}$ $s^{-1}$, respectively. 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. The initial soil fertility of calcareous soil was found to be medium in organic carbon (5.20 g $kg^{-1}$), available N (135 kg $ha^{-1}$), available P (14 kg $ha^{-1}$) and high in available K (736 kg $ha^{-1}$) and in non-calcareous soil, the initial status found to be medium in organic carbon (5.25 g $kg^{-1}$) and low in available N (186 kg $ha^{-1}$) and high in available P (33 kg $ha^{-1}$) and high in available K (795 kg $ha^{-1}$).

## Results and Discussion

### SPAD values

The SPAD chlorophyll values are related to chlorophyll content of the crop. Application of potassium @ 120 kg $ha^{-1}$ ($T_4$) recorded the highest SPAD value of 36.5 and 41.0 at vegetative and tasselling stage, respectively. Whereas in harvest stage, potassium @ 120 kg $K_2O$ $ha^{-1}$ (30.0) was found to be on par with potassium @ 80 kg $K_2O$ $ha^{-1}$ (29.0) (Table 1).

In non-calcareous soil ($S_2$), potassium @ 120 kg $ha^{-1}$ ($T_4$) with the SPAD value of 43.2, 47.6 an 38.3 was found to be on par with potassium @ 80 kg $ha^{-1}$ ($T_3$) (41.0, 45.9 and 37.2) at vegetative, tasselling and harvest stages (Table 1). Absolute control recorded the lowest SPAD values in all the growth stages in calcareous and non-calcareous soil.

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.

### 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 (1.48) and at vegetative stage. Potassium @ 120 kg $K_2O$ $ha^{-1}$ (3.51) found to be on par with potassium @ 80 kg $K_2O$ $ha^{-1}$ at tasselling stage. In harvest stage, potassium @ 120 kg $ha^{-1}$ recorded the highest leaf area index in calcareous soil ($S_1$) (Table 2).

In non-calcareous soil ($S_2$), potassium @ 120 kg $K_2O$ $ha^{-1}$ was found to be on par with potassium @ 80 kg $K_2O$ $ha^{-1}$ at vegetative stage. Potassium @ 120 kg $K_2O$ $ha^{-1}$ recorded the highest leaf area index at tasselling stage. Whereas in harvest stage, potassium @ 120 kg $ha^{-1}$ was found to be on par with potassium @ 80 kg $K_2O$ $ha^{-1}$. Control ($T_1$) recorded the lowest leaf area index at all stage of crop growth in calcareous and non-calcareous soil (Table 2).

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).

### Photosynthetic rate

Plant nutrition studies have identified potassium as the only monovalent cation that is essential for higher plants. Potassium is the most abundant cation in plant tissue and plays a major role in various physiological and biochemical processes, including photosynthesis. Application of potassium @ 120 kg $ha^{-1}$ ($T_4$) recorded the highest photosynthetic rate of 31.8 and 32.0 μ mol $CO_2$ $m^{-2}$ $s^{-1}$ in calcareous ($S_1$) and non-calcareous soil ($S_2$), respectively (Table 3).

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 (Egilla *et al.,* 2005).

## Stomatal conductance

One of the major functions of the stomata is to control plant water loss via transpiration. K plays a crucial role in turgor regulation within the guard cells during stomatal movement (Marschner, 2012). Application of potassium @ 120 kg $ha^{-1}$ ($T_4$) recorded the highest stomatal conductance of 0.20 m mol $m^{-2}$ $s^{-1}$ found to be on par with potassium @ 80 kg $K_2O$ $ha^{-1}$ (0.19 m mol $m^{-2}$ $s^{-1}$) at vegetative stage, whereas potassium @ 120 kg $K_2O$ $ha^{-1}$ recorded the highest stomatal conductance of 0.24 m mol $m^{-2}$ $s^{-1}$ in calcareous soil ($S_1$) (Table 3).

In non-calcareous soil ($S_2$), potassium @ 120 kg $K_2O$ $ha^{-1}$ (0.20 m mol $H_2O$ $m^{-2}$ $s^{-1}$) found to be on par with potassium @ 80 kg $K_2O$ $ha^{-1}$ (0.19 m mol $H_2O$ $m^{-2}$ $s^{-1}$) at vegetative stage, whereas in harvest stage, potassium @ 120 kg $K_2O$ $ha^{-1}$ recorded the highest evapo transpiration rate of 0.25 m mol $H_2O$ $m^{-2}$ $s^{-1}$ which were found to be on par with potassium @ 80 kg $K_2O$ $ha^{-1}$ ($T_3$) and potassium @ 40 kg $K_2O$ $ha^{-1}$($T_2$) at harvest stage (Table 3).

As stomatal closure is preceded by a rapid release of $K^+$ from the guard cells into the leaf apoplast, it is reasonable to think that stomata would be difficult to remain open under K-deficient conditions. Some studies also stated that K deficiency may induce stomatal closure and inhibit photosynthetic rates in several crop plants (Jin *et al.,* 2011).

This discrepancy may be related to the plant species, experimental system and environmental factors within the experimental field or interspecific differences. Benlloch-Gonzalez *et al.,* (2010) explained that the low plant K status could inhibit water-stress-induced stomatal closure via ethylene synthesis, and stomatal conductance could be significantly reduced. Then, the increased ethylene could inhibit the action of abscisic acid (ABA) on stomata and delay stomata closure (Tanaka *et al.,* 2006).

## Grain and straw yield

Grain yield is determined by the dry matter production of maize which will reflect the transport of nutrients from source to ink. Increased physiological activity increases the nutrient transport which ultimately leads to increase in grain and stover yield.

In calcareous soil, application of potassium @ 120 kg $K_2O^{-1}$ has recorded the highest stover and grain yield of maize with 100.2 g $plant^{-1}$ and 62.2 g $plant^{-1}$. Whereas in non-calcareous soil, potassium @ 120 kg $K_2O$ $ha^{-1}$ (106.2 and 66.9 g $plant^{-1}$) was found to be on par with potassium @ 80 kg $K_2O$ $ha^{-1}$ (105.9 and 66.5 g $plant^{-1}$) stover and grain yield, respectively (Table 4).

The increase in yield due to K application might be due to increase in leaf area and chlorophyll content producing higher net assimilation due to additional supply of potassium. Increase in grain yield and stover yield might be increase in potash level, it increased the rate of $CO_2$ assimilation, stabilized the osmosis regulation, improved stomata closure and enzyme activity as a result of which more carbohydrates might have produced which might have increased grain yield and stover yield (Tabatabaii *et al.*, 2011).

The results indicated that significant and positive correlation was existing between stover yield with physiological parameters (*viz*., Leaf area index and Photosynthetic rate) of maize ($R^2$= 0.841* and 0.970**) in calcareous soil ($S_1$). Whereas in non-calcareous soil ($S_2$), the significant positive correlation exist between stover yield with physiological parameters (*viz*., Photosynthetic rate and stomatal conductance) of maize ($R^2$ = 0.885*, 0.825*) (Table 5). The significant and positive correlation was existing between grain yield with physiological parameters (*viz*., Leaf area index, Photosynthetic rate and stomatal conductance) of maize ($R^2$= 0.851*, 0.962** and 0.985**) in calcareous soil ($S_1$). Whereas in non-calcareous soil ($S_2$), the significant positive correlation exist between stover yield with physiological parameters (*viz*., Photosynthetic rate and stomatal conductance) of maize ($R^2$ = 0.886* and 0.859*) (Table 5).

**Table.1** Effect of different levels of potassium on SPAD value of hybrid maize

| | Calcareous soil | | | Non- calcareous soil | | |
|---|---|---|---|---|---|---|
| | Vegetative | Tasselling | Harvest | Vegetative | Tasselling | Harvest |
| $T_1$ – Control | 21.5 | 34.3 | 27.0 | 36.7 | 41.6 | 35.0 |
| $T_2$- 40 kg $K_2O$ $ha^{-1}$ | 27.5 | 36.7 | 28.0 | 39.0 | 44.3 | 36.1 |
| $T_3$- 80 kg $K_2O$ $ha^{-1}$ | 32.4 | 38.9 | 29.0 | 41.0 | 45.9 | 37.2 |
| $T_4$- 120 kg $K_2O$ $ha^{-1}$ | 36.5 | 41.0 | 30.0 | 43.2 | 47.6 | 38.3 |
| S Ed | 0.589 | 0.284 | 0.499 | 0.97 | 0.67 | 0.66 |
| CD (P=0.05) | 1.359 | 0.654 | 1.150 | 2.23 | 1.55 | 1.51 |

**Table.2** Effect of different levels of potassium on Leaf Area Index (LAI) of hybrid maize

| | Calcareous soil | | | Non- calcareous soil | | |
|---|---|---|---|---|---|---|
| | Vegetative | Tasselling | Harvest | Vegetative | Tasselling | Harvest |
| $T_1$ – Control | 1.16 | 2.90 | 3.10 | 1.28 | 3.12 | 3.30 |
| $T_2$- 40 kg $K_2O$ $ha^{-1}$ | 1.30 | 3.17 | 3.38 | 1.39 | 3.33 | 3.53 |
| $T_3$- 80 kg $K_2O$ $ha^{-1}$ | 1.42 | 3.36 | 3.50 | 1.47 | 3.52 | 3.64 |
| $T_4$- 120 kg $K_2O$ $ha^{-1}$ | 1.48 | 3.51 | 3.58 | 1.53 | 3.67 | 3.71 |
| S Ed | 0.021 | 0.080 | 0.069 | 0.04 | 0.06 | 0.08 |
| CD (P=0.05) | 0.049 | 0.185 | 0.158 | 0.10 | 0.15 | 0.18 |

**Table.3** Effect of different levels of potassium on photosynthetic rate and stomatal conductance of hybrid maize in calcareous soil ($S_1$) and non- calcareous soil ($S_2$)

| | Calcareous soil | | | | Non- calcareous soil | | | |
|---|---|---|---|---|---|---|---|---|
| | Photosynthetic rate (μ mol $CO_2$ $m^{-2}s^{-1}$) | | Stomatal Conductance (m mol $m^{-2}$ $s^{-1}$) | | Photosynthetic rate (μ mol $CO_2$ $m^{-2}s^{-1}$) | | Stomatal Conductance (m mol $m^{-2}$ $s^{-1}$) | |
| | Vegetative | Harvest | Vegetative | Harvest | Vegetative | Harvest | Vegetative | Harvest |
| **$T_1$ – Control** | 33.2 | 20.2 | 0.10 | 0.20 | 34.3 | 24.7 | 0.12 | 0.22 |
| **$T_2$- 40 kg $K_2O$ $ha^{-1}$** | 33.8 | 26.1 | 0.13 | 0.23 | 35.2 | 28.0 | 0.17 | 0.24 |
| **$T_3$- 80 kg $K_2O$ $ha^{-1}$** | 34.4 | 30.0 | 0.14 | 0.23 | 35.6 | 30.4 | 0.19 | 0.25 |
| **$T_4$- 120 kg $K_2O$ $ha^{-1}$** | 34.8 | 31.8 | 0.14 | 0.24 | 35.7 | 32.0 | 0.20 | 0.25 |
| **S Ed** | 0.925 | 0.383 | 0.002 | 0.005 | 0.75 | 0.55 | 0.002 | 0.004 |
| **CD (P=0.05)** | NS | 0.882 | 0.005 | 0.011 | NS | 1.27 | 0.005 | 0.009 |

**Table.4** Effect of different levels of potassium on stover yield and grain yield of maize in calcareous ($S_1$) and non- calcareous soil ($S_2$)

| | Calcareous soil | | Non- calcareous soil | |
|---|---|---|---|---|
| | Stover yield | Grain yield | Stover yield | Grain yield |
| **$T_1$ – Control** | 56.0 | 35.0 | 77.1 | 48.0 |
| **$T_2$- 40 kg $K_2O$ $ha^{-1}$** | 73.6 | 46.2 | 93.0 | 58.1 |
| **$T_3$- 80 kg $K_2O$ $ha^{-1}$** | 88.6 | 55.3 | 105.9 | 66.5 |
| **$T_4$- 120 kg $K_2O$ $ha^{-1}$** | 100.2 | 62.2 | 106.2 | 66.9 |
| **S Ed** | 0.80 | 1.16 | 1.69 | 0.68 |
| **CD (P=0.05)** | 1.84 | 2.69 | 3.90 | 1.57 |

**Table.5** Correlation between stover yield and grain yield with physiological parameters of maize in calcareous ($S_1$) and non- calcareous soil ($S_2$)

| | Calcareous soil | | Non- calcareous soil | |
|---|---|---|---|---|
| | Stover yield | Grain yield | Stover yield | Grain yield |
| **SPAD values** | - | - | - | - |
| **Leaf area index** | 0.841* | 0.851* | - | - |
| **Photosyntheic rate** | 0.970** | 0.962** | 0.885* | 0.886* |
| **Stomatal conductance** | - | - | 0.825* | 0.859* |

The experimental results indicated that in calcareous soil, at vegetative stage, physiological parameters viz., SPAD values, Leaf Area Index and Photosynthetic rate responded well up to potassium @ 120 kg $K_2O$ $ha^{-1}$; at tasselling stage, SPAD values responded well up to 120 kg $K_2O$ $ha^{-1}$ whereas leaf area index showed significant response up to 80 kg $K_2O$ $ha^{-1}$; at harvest stage, SPAD values showed response up to potassium @ 80 kg $K_2O$ $ha^{-1}$ and for leaf are index, Photosynthetic rate and stomatal conductance showed response up to potassium @ 120 kg $K_2O$ $ha^{-1}$.

In non-calcareous soil at vegetative, tasselling and harvest stages, SPAD values and Leaf Area Index showed significant response up to potassium @ 80 kg $K_2O$ $ha^{-1}$ whereas photosynthetic rate and stomatal conductance showed response up to 120 kg $K_2O$ $ha^{-1}$. In calcareous there is a positive significant correlation occurs between grain and stover yield of hybrid maize with physiological parameters like leaf area and photosynthetic rate in calcareous soil, grain and stover yield of hybrid maize correlated with photosynthetic rate and stomatal conductance. The study elucidates that potassium availability is necessary for calcareous soil at critical stages of maize.

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