# Effect of Potassium and Zinc Nutrition on Growth and Yield of Short Duration Maize (*Zea mays* L.) under Dryland *Vertisols*

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## ABSTRACT

**Background:** The black soils (*vertisols*) are often considered to be high in potassium content however; under intensive cultivation of high nutrient demanding crop like maize; the soil available potassium might not be sufficient to fulfil the demand. Moreover; the interaction between potassium and micronutrients like zinc has to evaluated for higher crop yield under dryland condition.

**Methods:** The experiment was laid out in factorial RBD design with two factors, i.e., potassium (K) and zinc (Zn), with three levels of each ($K_1$- 30 kg $K_2O$ $ha^{-1}$, $K_2$- 60 kg $K_2O$ $ha^{-1}$, $K_3$- 90 kg $K_2O$ $ha^{-1}$; $Zn_1$- 20 kg $ZnSO_4$ $ha^{-1}$, $Zn_2$- 30 kg $ZnSO_4$ $ha^{-1}$ and $Zn_3$- 40 kg $ZnSO_4$ $ha^{-1}$).

**Result:** Statistical interpretation of experimental data revealed that application of potassium at 60 kg $K_2O$ $ha^{-1}$ and 30 kg of $ZnSO_4$ $ha^{-1}$ resulted improved plant height, number of functional leaves $plants^{-1}$, leaf area index, dry matter accumulation, grain yield, stover yield and shelling percentage in maize. Interestingly positive interaction has also been recorded between potassium and zinc nutrition.


**Key words:** Growth, Maize, Potassium, Yield, Zinc.

## INTRODUCTION

The prominence of maize is only next to rice and wheat in India and currently contributing 9% of India's national food basket (Kiran*et al.*, 2018). Maize has been bestowed with the titles of "*Queen of cereals*" and "*poor men's nutria-cereal*" due to higher productivity, low cost of cultivation, higher response toward fertilizer input, a higher level of dietary protein, fat, minerals and vitamins (Alamerew, 2008; Jaliya *et al.*, 2008). However, maize's higher production is subjected to the adequate supply of plant macro and micronutrients as maize is highly responsive to fertilizer inputs. When it comes to nutrient requirement, maize is susceptible to available soil fractions of potassium and zinc significantly when growing under challenging conditions (Farooq *et al.,* 2015).

Raising maize in the dryland *vertisols* tract of western India faces some unique challenges, including imbalanced nutrient management. The decades' old researches indicate that better INM coupled with adequate soil moisture can significantly improve crop yield in this region and maize is no exception.

The general notion of black soils (*vertisols*) being rich in potassium has resulted in a lower potassium application rate by the farmers, which could be the growth and yield-limiting factor of maize for this area. However, a significant portion of Indian *vertisols* is dominated by the beidellite-nontronite type of minerals, which often becomes exhausted of exchangeable and soil solution K, especially in the case of high nutrient demanding crop such as maize. This reduction of K availability is even more manifested when the soil is flooded with water after a long dry season or in case of excessive (Ca+Mg)/K situation, which leads to reduced K concentration in soil solution, thus high yielding crop fails to uptake required quantity of K desirable for enhanced production (Dobermann *et al.*, 2002). The increased productivity of any crop requires more K and a faster release rate in the soil, which can only be met by external application by fertilizer.

On the other hand, zinc is one of the essential micronutrients, yet 50% of the world's soil is deficient in Zn (Welch, 1993). The Zn deficiency is wide- spread in India (Shivay and Prasad, 2014) and most prevalent in dry calcareous soils (Katyal and Vlek, 1985), prominently found in Maharashtra's dryland tract. The deficiency of Zn on soil deters sound plant growth (Behera *et al.*, 2015) and causes Zn deficiency in human, which the fifth principal risk factor for disease in emerging countries like India (Guilbert, 2003).

The interaction between potassium and zinc is another aspect which is needed to be studied, especially in Indian

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condition. Considering all these factors, the field experiment was conducted explore potassium and zinc nutrition's integrated effect on maize under dryland condition.

## MATERIALS AND METHODS

This experiment was initiated during the *Kharif* season of 2016 at, Agronomy Research Block of Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra, India. The experimental plot is located between 20.69°N latitude, 77°E longitude and 283.2 m above mean sea level. The summed up meteorological data recorded by the institutional weather station has been presented in Table 1. The physiochemical properties of soil of the experimental site (before *Kharif* 2016) are presented in Table 2.

Factorial Randomized Block Design (FRBD) with two factors, *i.e.*, potassium ($K_2O$) and Zinc ($ZnSO_4$) fertilization and each with three levels was chosen as experimental design; keeping in mind to find out their individual as well as an interaction effect. The three K levels were $K_{30}$- 30 kg $K_2O$ $ha^{-1}$, $K_{60}$- 60 kg $K_2O$ $ha^{-1}$ and $K_{90}$- 90 kg $K_2O$ $ha^{-1}$. In case of Zn; the constituent three levels were $Zn_{20}$- 20 kg $ZnSO_4$ $ha^{-1}$, $Zn_{30}$- 30 kg $ZnSO_4$ $ha^{-1}$ and $Zn_{40}$- 40 kg $ZnSO_4$ $ha^{-1}$ respectively. Each treatment consists of combinations of K and Zn replicated thrice and applied in a gross plot of 24 $m^2$ area. The combination of 30 kg $ha^{-1}$ of $K_2O$ and 20 kg $ha^{-1}$ of $ZnSO_4$ ($K_{30}$:$Zn_{20}$) is the commonly used dose of K and Zn of this region and widely practised by the farmer hence it was taken as control.

A nitrogen dose of 120 kg N $ha^{-1}$ and phosphorus dose of 60 kg $P_2O_5$ $ha^{-1}$ was applied to all the treatments using urea and SSP. The phosphorus was applied entirely as a basal dose during the sowing, while nitrogen was applied in two split doses; the 1st was during the sowing and the second one as a top dressing at 30 DAS. Muriate of potash was uniformly broadcasted to the plots as per the assigned treatments. The zinc was applied by dissolving zinc sulphate heptahydrate in water (15 litre of water per kg of $ZnSO_4$) followed by spraying near the crop rows.

The short duration dwarf variety *Ravi*- 81 was sown with a seed rate of 20 kg $ha^{-1}$ by following a spacing of 60 × 20 cm and a uniform sowing depth of 5 cm using dibbling method. Thinning and gap-filling operation was performed following the recommended procedures to keep an equal number of plants per plot.

Five plants have been randomly selected from each plot and duly tagged; subsequently, these plants are used to record non-destructive biometric observations such as the plant's height, the number of functional leaves, leaf area, etcetera. Similarly, five plants were uprooted from the plot for destructive sampling in each interval which were sundried followed by oven dried at a constant temperature of 65°C.

The plant height was recorded at 20, 40, 60, 80 DAS and at the final harvesting stage. The number of functional leaves was enumerated on a plant basis while the leaf area was measured using a table top *biovis* leaf area meter. Leaf area index was estimated by dividing the leaf area per plant by the ground area occupied by that plant (Sestak *et al*. 1971). The chlorophyll content was measured using a SPAD 502 (Konica, Minolta Sensing line, Japan), Chlorophyll meter, and expressed in SPAD unit.

The recorded replicated mean data were analysed for ANOVA, critical difference of means, *post-hoc* analysis (Duncan multiple range test) and path coefficient analysis by following the standard procedure mentioned by Gomez and Gomez (1984) using R statistical programme (Rstudio, V-1.3.1093, 2020) with Agricole package.

## RESULTS AND DISCUSSION

### Plant growth attributes and dry matter accumulation

The various growth and development parameters of maize were found to be significantly affected by both potassium and zinc application either due to interaction or due to stand alone affect.

Plant height (Fig 1A) of maize was well responded and increased under different levels of potassium and zinc application except for the initial stages of 20 DAS. Although the interaction between different levels of potassium and zinc has abortive to produce any significant result; the individual effect was significant. The maximum plant height was recorded at 60 kg $K_2O$ $ha^{-1}$ which was 17.42, 5.62, 5.34 and 5.03% more than 30 kg $K_2O$ $ha^{-1}$ at 40, 60, 80 DAS and at harvest stage. The increase of plant height due to potassium can be argued due to the enhanced activity of Auxin (Marre, 1977).

In case of zinc application; the plots which received 30 kg $ha^{-1}$ of $ZnSO_4$ recorded the tallest plant height which were 10.56, 3.64, 4.71 and 4.72% taller than 20 kg/ha of $ZnSO_4$ however found to at par with 40 kg $ha^{-1}$ of $ZnSO_4$. Such kind of increment due to zinc application is a result of higher nitrogen uptake and enhanced enzymatic activity (Mahdi *et al*., 2012).

**Table 1:** Meteorological observations during study period.

| Month | Temperature (°C) | | Relative humidity (%) | | Total rainfall (mm) | Total evaporation (mm) |
|---|---|---|---|---|---|---|
| | Mean maximum | Mean minimum | Mean maximum | Mean minimum | | |
| 20-30 June | 35.4 | 26.1 | 72.66 | 44.33 | 139.7 | 28.1 |
| 1-31 July | 30.58 | 24.3 | 87.2 | 69.6 | 376.1 | 20.7 |
| 1-31 August | 30.54 | 23.84 | 84.25 | 62.5 | 30.7 | 17.5 |
| 1-30 September | 31.34 | 23.4 | 88.4 | 61.8 | 123.2 | 18.2 |
| 1-20 October | 31.1 | 20.2 | 87.46 | 53.63 | 90.5 | 11.7 |

Similarly, the number of functional leaves/plants was also found to be higher when potassium was applied at a rate of 60 kg $K_2O$ $ha^{-1}$ and zinc was applied at a rate of 30 kg $ZnSO_4$ $ha^{-1}$ at 40 and 60 DAS (Fig 1B). The higher number of leaves is a sign of higher source space formation for photosynthesis (Kubar *et al.,* 2013; Ebrahimi et *al*., 2011).

The SPAD recorded highest greenness index when potassium was applied at 60 kg $K_2O$ $ha^{-1}$ as it recorded 29, 21.70 and 21.27% higher SPAD value than 30 kg $K_2O$ $ha^{-1}$ at 40, 60 and 80 DAS (Fig 1C). Similarly; application of 30 kg $ZnSO_4$ $ha^{-1}$ recorded 6.5, 5.93, 5.95% more SPAD value than 20 kg $ZnSO_4$ $ha^{-1}$.

**Table 2:** Initial physio chemical status of experimental site prior to the experiment.

| Particulars | Result |
|---|---|
| **Mechanical analysis** | |
| Sand (%) | 25.00 |
| Silt (%) | 30.00 |
| Clay (%) | 45.00 |
| Textural class | Clayey |
| **Soil reaction** | |
| pH | 8.5 |
| EC($Dsm^{-1}$) | 0.27 |
| **Chemical analysis** | |
| Walkley - Black C (%) | 0.5 |
| $KMnO_4$ Oxidizable N (kg $ha^{-1}$) | 201 |
| 0.5 M $NaHCO_3$ extractable P (kg $ha^{-1}$) | 15.79 |
| 1N $NH_4OAC$ extractable K (kg $ha^{-1}$) | 367.30 |
| DTPA extractable Zn ($mgkg^{-1}$) | 0.46 |

The leaf area index (LAI) has been found to be equally improved by the application of potassium and zinc (interaction effect was significant) during the active growth period of 40 DAS, 60 DAS and 80 DAS (Table 3). The data indicated that increase in K application maximized the LAI up to 60 kg $K_2O$ $ha^{-1}$ but at 90 kg $K_2O$ $ha^{-1}$ it declined. In case of zinc; the augmentation of $ZnSO_4$, however, resulted in a positive trend even up to 40 kg of $ZnSO_4$ $ha^{-1}$. At 40 DAS, the highest leaf area index was observed on $K_1Zn_3$ (30:40), which was found to be at par with $K_2Zn_1$ (60:20). This is maybe since *Vertisols* are generally rich in potassium, but only a small pool of soil solution potassium is readily available (Mc Lean *et al.,*1985). As a result, in case of the fast-growing and heavy feeder crop like maize responded well to the additional amendment of potassium and zinc in early active growth stages (Zhang *et al*., 2013).

Application of both potassium and zinc resulted in higher dry matter accumulation (Table 4). This could be attributed to enhanced plant height, leaf area index and photosynthates accumulation, thereby improving the plant vigour due to source-sink relationship (Hussain *et al.,* 2015). The two-way interaction table (Table 4) depicts how gradually increasing zinc fertilization in the presence of escalating potassium

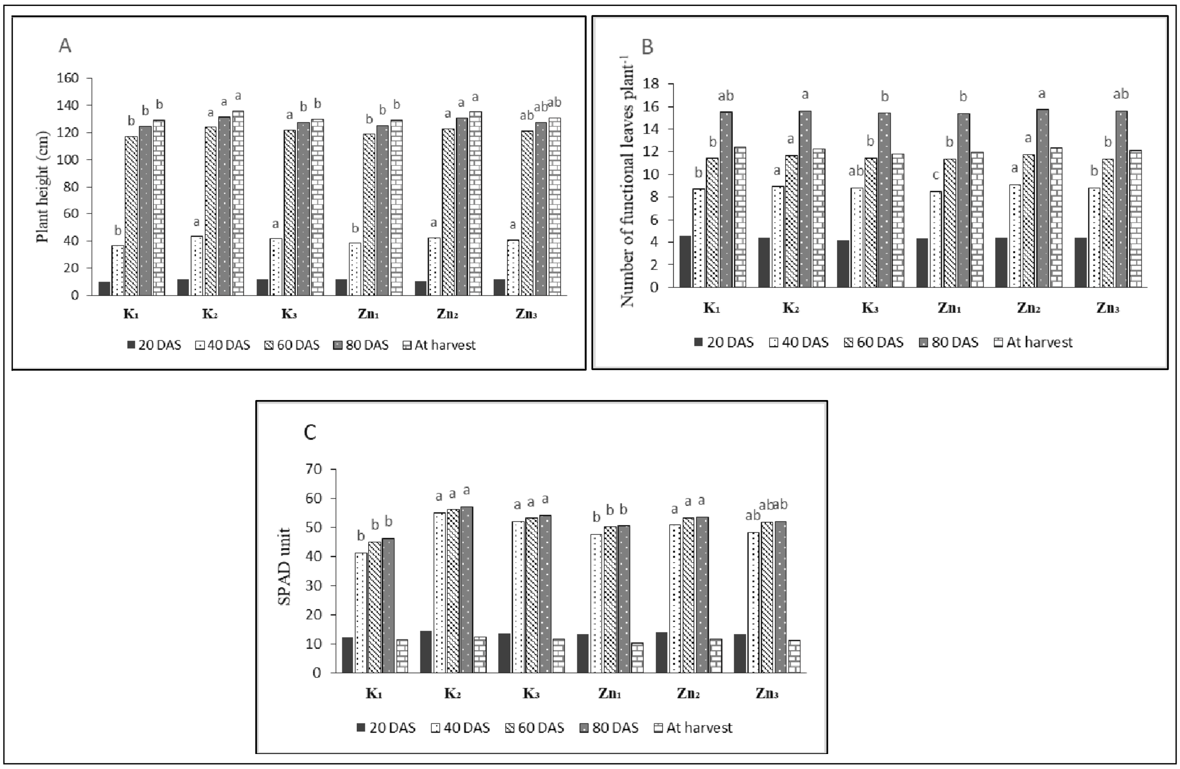


**Fig 1:** (A) Number of functional leaves $plant^{-1}$ (B) and relative chlorophyll content or SPAD unit (C) at different growth stages of maize. (DAS= Days after sowing, $K_1$= 30 kg $K_2O$ $ha^{-1}$, $K_2$= 60 kg $K_2O$ $ha^{-1}$, $K_3$= 90 kg $K_2O$ $ha^{-1}$, $Zn_1$= 20 kg $ZnSO_4$ $ha^{-1}$, $Zn_2$= 30 kg $ZnSO_4$ $ha^{-1}$ and $Zn_3$= 40 kg $ZnSO_4$ $ha^{-1}$. Bars with no alphabetic ranking are not statistically significant).

**Table 3:** Effect of two-way interaction between potassium and zinc on leaf area index (LAI) of maize at 40, 60 and 80 days after sowing.

| | LAI at 40 DAS | | | | LAI at 60 DAS | | | | LAI at 80 DAS | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $Zn_1$ | $Zn_2$ | $Zn_3$ | Mean | $Zn_1$ | $Zn_2$ | $Zn_3$ | Mean | $Zn_1$ | $Zn_2$ | $Zn_3$ | Mean |
| $K_1$ | $1.14^f$ | $1.17^f$ | $2.56^a$ | 1.62 | $2.63^f$ | $2.71^{ef}$ | $3.9^a$ | 3.08 | $4.37^d$ | $4.53^{cd}$ | $5.88^a$ | 4.93 |
| $K_2$ | $1.74^b$ | $1.78^b$ | $1.98^{cd}$ | 1.83 | $3.0^b$ | $3.5^b$ | $3.63^c$ | 3.38 | $5.65^a$ | $5.40^{ab}$ | $4.92^{bc}$ | 5.32 |
| $K_3$ | $1.23^f$ | $1.48^e$ | $1.54^{de}$ | 1.42 | $2.78^{def}$ | $2.94^{cde}$ | $3.03^{cd}$ | 2.92 | $4.49^{cd}$ | $4.83^{cd}$ | $4.91^{bc}$ | 4.74 |
| Mean | | 1.37 | 1.48 | 2.02 | | 2.8 | 3.05 | 3.52 | | 4.84 | 4.92 | 5.23 |
| S Em ± | | 0.071 | | | | 0.093 | | | | 0.168 | | |
| CD (P=0.05) | | 0.212 | | | | 0.268 | | | | 0.503 | | |

(DAS= Days after sowing, $K_1$= 30 kg $K_2O$ ha$^{-1}$, $K_2$= 60 kg $K_2O$ ha$^{-1}$, $K_3$= 90 kg $K_2O$ ha$^{-1}$, $Zn_1$= 20 kg $ZnSO_4$ ha$^{-1}$, $Zn_2$= 30 kg $ZnSO_4$ ha$^{-1}$ and $Zn_3$= 40 kg $ZnSO_4$ ha$^{-1}$. Means possessing same letter does not differ statistically according to Duncan multiple range test at 5% probability).

**Table 4:** Dry matter accumulation (g) in vegetative part of maize plant (excluding cob) as influenced by interaction between potassium (K) and zinc (Zn) at 40, 60, 80 days after sowing and at final harvest stage.

| | $Zn_1$ | $Zn_2$ | $Zn_3$ | Mean | $Zn_1$ | $Zn_2$ | $Zn_3$ | Mean |
|---|---|---|---|---|---|---|---|---|
| | **40 DAS** | | | | **60 DAS** | | | |
| $K_1$ | $24.53^b$ | $25.29^b$ | $24.30^b$ | 24.71 | $47.57^c$ | $48.31^c$ | $46.82^c$ | 47.57 |
| $K_2$ | $27.57^a$ | $25.77^b$ | $24.69^b$ | 26.01 | $54.07^a$ | $52.07^b$ | $46.91^c$ | 51.02 |
| $K_3$ | $24.43^b$ | $24.23^b$ | $24.10^b$ | 24.25 | $47.23^c$ | $47.12^c$ | $47.67^c$ | 47.34 |
| Mean | 25.51 | 25.1 | 24.36 | | 49.62 | 49.17 | 47.13 | |
| S Em ± | 0.78 | | | | 1.04 | | | |
| CD (P=0.05) | 2.33 | | | | 3.13 | | | |
| | **80 DAS** | | | | **At harvest** | | | |
| $K_1$ | $59.54^c$ | $60.29^c$ | $58.87^c$ | 59.57 | $69.6^c$ | $70.11^c$ | $68.7^{cd}$ | 69.47 |
| $K_2$ | $68.03^a$ | $65.75^b$ | $64.32^b$ | 66.03 | $78.19^a$ | $75.5^b$ | $74.24^b$ | 75.98 |
| $K_3$ | $56.01^d$ | $56.04^d$ | $56.45^d$ | 56.17 | $66.87^e$ | $67.05^{de}$ | $67.27^{de}$ | 67.06 |
| Mean | 61.19 | 60.69 | 59.88 | | 71.55 | 70.89 | 70.07 | |
| S Em ± | 1.19 | | | | 0.70 | | | |
| CD (P=0.05) | 3.57 | | | | 2.10 | | | |

(DAS= Days after sowing, $K_1$= 30 kg $K_2O$ ha$^{-1}$, $K_2$= 60 kg $K_2O$ ha$^{-1}$, $K_3$= 90 kg $K_2O$ ha$^{-1}$, $Zn_1$= 20 kg $ZnSO_4$ ha$^{-1}$, $Zn_2$= 30 kg $ZnSO_4$ ha$^{-1}$ and $Zn_3$= 40 kg $ZnSO_4$ ha$^{-1}$. Columns not having alphabetic ranking are not statistically significant. Means followed by same letter does not differ statistically according to Duncan multiple range test at 5% probability).

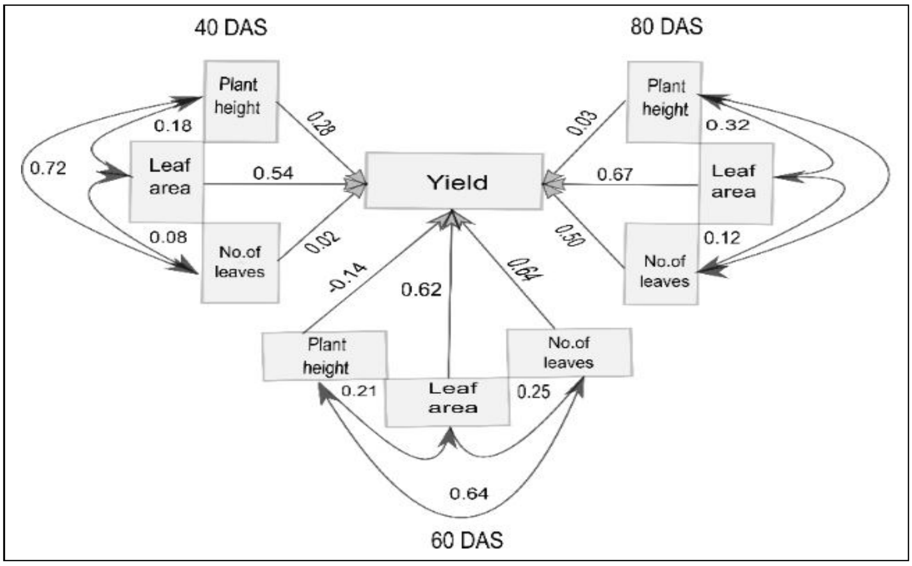


**Fig 2:** Path coefficient analysis indicating relationship among plant height, leaf area, number of functional leaves and grain yield at different active vegetative growth stages as influenced by combined application of potassium and zinc.

**Table 5:** Effect of different doses of potassium (K) and zinc (Zn) on grain yield (kg $ha^{-1}$), stover yield (kg $ha^{-1}$) and Shelling percentage (%).

| Treatments | Grain yield (kg $ha^{-1}$) | Stover yield (kg $ha^{-1}$) | Shelling percentage (%) |
|---|---|---|---|
| **Levels of potassium (K)** | | | |
| $K_1$ - 30 kg $K_2O$ $ha^{-1}$ | 3611 | 9227.93 | $76.24^b$ |
| $K_2$ - 60 kg $K_2O$ $ha^{-1}$ | 4208 | 9604.52 | $80.01^a$ |
| $K_3$ - 90 kg $K_2O$ $ha^{-1}$ | 3585 | 9289.8 | $74.99^b$ |
| S Em ± | 35.575 | 38.392 | 1.161 |
| CD at (P=0.05) | 106.642 | 115.090 | 3.481 |
| **Levels of zinc (Zn)** | | | |
| $Zn_1$ - 20 kg $ZnSO_4$ $ha^{-1}$ | 3779.47 | 9331.45 | $73.32^b$ |
| $Zn_2$ - 30 kg $ZnSO_4$ $ha^{-1}$ | 3902.74 | 9513.13 | $81.69^a$ |
| $Zn_3$ - 40 kg $ZnSO_4$ $ha^{-1}$ | 3722.53 | 9277.55 | $76.23^b$ |
| S Em ± | 35.575 | 38.392 | 1.161 |
| CD (P=0.05) | 106.642 | 115.090 | 3.481 |
| **Interactions (K x Zn)** | | | |
| S Em ± | 61.618 | 66.499 | 2.011 |
| CD (P=0.05) | 184.710 | 199.342 | NS |

**Table 5.1:** Grain yield (kg $ha^{-1}$) and stover yield (kg $ha^{-1}$) as effected by interaction between different doses of potassium (K) and zinc (Zn) Grain yield (kg $ha^{-1}$) Stover yield (kg $ha^{-1}$).

| | $Zn_1$ | $Zn_2$ | $Zn_3$ | Mean | $Zn_1$ | $Zn_2$ | $Zn_3$ | Mean |
|---|---|---|---|---|---|---|---|---|
| $K_1$ | $3250^f$ | $3583^{de}$ | $4000^c$ | 3611 | $9305^{cd}$ | $9327^c$ | $9237^{cd}$ | 9290 |
| $K_2$ | $4250^b$ | $4708^a$ | $3667^{de}$ | 4208 | $9628^{ab}$ | $9783^a$ | $9402^{bc}$ | 9604 |
| $K_3$ | $3505^e$ | $3750^d$ | $3501^e$ | 3585 | $9428^{bc}$ | $9193^{cd}$ | $9061^d$ | 9227 |
| Mean | 3668 | 4014 | 3723 | | 9454 | 9434 | 9233 | |
| S Em ± | 61.61 | | | | 66.49 | | | |
| CD (P=0.05) | 184.71 | | | | 199.34 | | | |

($K_1$= 30 kg $K_2O$ $ha^{-1}$, $K_2$= 60 kg $K_2O$ $ha^{-1}$, $K_3$= 90 kg $K_2O$ $ha^{-1}$, $Zn_1$= 20 kg $ZnSO_4$ $ha^{-1}$, $Zn_2$= 30 kg $ZnSO_4$ $ha^{-1}$ and $Zn_3$= 40 kg $ZnSO_4$ $ha^{-1}$. Columns not having alphabetic ranking are not statistically significant. Means possessing same letter does not differ statistically according to Duncan multiple range test at 5% probability).

dosage effects the dry matter accumulation in maize. Highest dry matter accumulation was observed when potassium was applied at the rate of 60 kg $K_2O$ $ha^{-1}$ along with 20 kg $ha^{-1}$ of $ZnSO_4$.

### Path coefficient analysis of growth attributes

Path analysis (Fig 2) of three active vegetative growth stages (40, 60 and 80 DAS) elucidates how collective application of potassium and zinc fertilizer rendered its effect on prominent growth attributes which finally influences the yield. These can be summed up as combined application of potassium and zinc resulted in enhanced plant height in earlier active vegetative growth stages which resulted in accommodation of a higher number of functional leaves; again, on the later stages, both nutrients resulted in larger leaf size which finally helped to attain higher the grain yield.

### Grain and stover yield

The interaction between 60 kg $K_2O$ $ha^{-1}$ and 30 kg $ZnSO_4$ $ha^{-1}$ also resulted highest grain yields (4708 kg $ha^{-1}$) and stover yield stover yield (9783 kg $ha^{-1}$) (Table 5 and 5.1). The higher grain yield and straw yield is due to better photosynthate mobilization as well as increase of the number of sink space. The increment of yield due to the stand-alone application of zinc on maize was also earlier reported by Kumar *et al.* (2017) and Panda *et al.* (2019).

## CONCLUSION

This study conclusively indicates that combined application of potassium at a rate of 60 kg $K_2O$ $ha^{-1}$ along with 30 kg $ZnSO_4$ $ha^{-1}$ improves growth and yield of maize under dryland condition while in some cases positive interaction between potassium and zinc has also been observed.

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