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## Physiological & biochemical response of maize (*Zea mays* L.) to low grade rock phosphate under acidic soils of Odisha

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### Abstract

A field experiment entitled was conducted at central farm OUAT, Bhubaneswar under Department of Soil Science & Agricultural Chemistry during Kharif 2017. The physiological studies were carried out in the Department of Plant Physiology, College of Agriculture, Bhubaneswar. The result revealed that plant height, number of leaves and dry matter were improved by the level of P application. Among the treatments application of 100% P(SSP)+0.2% LR registered significant increase in of the above growth character in maize crop which reflect a higher value of LAI, CGR, RGR and lower value of NAR. Chlorophyll content was found to be maximum in T<sub>7</sub> (100% SSP + 0.2% LR) followed by T<sub>5</sub> (50% RP+50% SSP). The other nutritional components like carbohydrate, protein and sugar of grains increased significantly with increase in the level of P application. Higher concentration of nutrient elements (N, P, K and S) found maximum in 100% SSP + 0.2% LR in both grain and Stover. Among the different combination of RP and SSP, taller plant and highest no. of leaves were produced by application of 50% RP+50% SSP with higher dry matter accumulation. The biochemical traits like nutritional composition (carbohydrate, protein & sugar) found maximum with the application of 50% RP+50% SSP among the combined application. But in the combination of RP and SSP nutrient contents (N, P, K & S) found maximum with application of 25% RP+75% SSP in Stover and with the application of 50% RP+50% SSP found maximum in grain. The grain yield in maize increased significantly with increase in the level of P application due to increase in cob weight, no. of grain per plant, cob length, cob diameter, 100 seed weight and the highest yield registered among the treatments by the application of 100% SSP+0.2% LR. Among the combined application of 50% RP+50% SSP registered the highest yield over the sole application of either R or SSP. In view of the positive and beneficial effect of P application in maize crop it may be concluded that improvement in productive of maize crop by the use of low grade rock phosphate under acid soils can be possible through combined application of 50% RP + 50% SSP.

**Keywords:** Phosphorous, SSP (Single super phosphate), RP (Low grade rock phosphate), LR (Lime requirement)

### Introduction

Acid soils constitute about 30% of the total cultivable area in India. These soils are formed due to drastic weathering under hot humid climate and heavy precipitation. Acidic parent materials (granite), leaching of bases from the surface soils due to high rainfall, use of nitrogenous fertilizers like ammonium sulphate, ammonium nitrate, ammonium chloride and urea induces soil acidity. The acid soils are mostly distributed in Assam, Manipur, Tripura, Meghalaya, Mizoram, Nagaland, Sikkim, Arunachal Pradesh, West Bengal, Jharkhand, Orissa, Madhya Pradesh, Himachal Pradesh, Jammu & Kashmir, Andhra Pradesh, Karnataka, Kerala, Maharashtra and Tamil Nadu. It is estimated that about 12% soils are strongly acidic (pH < 5.0), 48% moderately acidic (pH 5.0-5.5) and 40% mildly acidic (pH 5.6-6.5). Soil acidity and poverty are synonymous in the state of Odisha where 80% of soils are acidic. Low water holding capacity, high bulk density, and soil crusting along with chemical constraints like low pH, low CEC, low base saturation (16 to 67%), high Al, Fe and Mn saturation, and high P-fixing capacity (80 to 91%) are major reasons for low crop productivity in such soils (Misra *et al.*, 1989). Phosphorus is one of the most limiting nutrient in the soils of Odisha owing to P fixation and immobile nature of P (Pattanayak *et al.*, 2008). Acid soils fix two-to-three times more P per unit surface area than neutral or calcareous soil and the fixed P in acid soil is held with five times more bonding energy than calcareous soils.

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The extent of P fixation from the added P varies from 97% under air-dry condition to 76% under submerged condition, which is dependent on the type and quantity of clay minerals, sesquioxide and organic matter content (Pattanayak and Misra, 1989). Even though the soils of Odisha are low (27%) to high (73%) in soil available P, crops grown in Odisha exhibited a significant yield loss due to omission of P, which is 37% in hybrid rice (Pattanayak *et al.*, 2008) and 49% in hybrid maize (Pattanayak *et al.*, 2009). Thus, a proper P management strategy is required for improving and sustaining crop yields in the acid soils of Odisha. The right source of P application in acid soils depends on the nature of growing environment. Under submerged soil conditions, owing to relatively less P fixation and high solubility of native P, application of readily available water soluble sources of P fertilizers are more appropriate. Such water-soluble sources are, however, less efficient for upland red and lateritic soils due to high P fixation. Pattanayak *et al.* (2011) reported that the unproductive/less productive acid upland soils (Alfisols, Inceptisols, and Entisols) can improve crop yields through application of the right nutrient rates based on soil testing, integrated with organic and inorganic soil ameliorants. P fertilizer applied at right time showed higher crop yields while improving the efficiency of applied P in the acidic soils of Odisha. Similarly, Arnall (2014) reported that in acid soils with low pH conditions, right placement of P fertilizers through banding helps to alleviate the impact of Al toxicity as phosphate reacts with metals like Al and Mn to form insoluble compounds and reduces the harmful effects of the metals on the emerging seedlings.

In India, there are about 49 M ha of soils of which about 25 M ha have pH less than 5.5 and 2.3 M ha have pH between 5.6 and 6.5. In these soils, there is an acute deficiency of phosphorus (P) which is the yield limiting nutrient in crop production. These soils are rich in sesquioxides, low in humus and have high P fixing capacity. In these soils, crops respond to applied P only after P fixing capacity of the soils is satisfied, justifying need for high levels of applied P to crop. Rock phosphate (RP) can supply P at a unit cost much lower than that from other commonly used fertilisers containing water soluble P and can be used as P source for agricultural production especially in acid soils. Research on the utilisation of RP as a direct fertiliser, especially in acid soils, has continued in India since the 1970s. In recent years the increase in price of phosphatic fertilizers and environmental pollution, practice of application of rock phosphate is definitely cheap and ecofriendly. The total reserves of rock phosphates in India are around 200M.T (Fertilizer Focus, 1991) comprising station of Andhra Pradesh, Madhya Pradesh, Tamil Nadu, West Bengal, Rajasthan etc. Mostly the indigenous rockphosphates are of low grade (<20% P<sub>2</sub>O<sub>5</sub>) but imported rockphosphates are of high grade (>30% P<sub>2</sub>O<sub>5</sub>). The efficiency of chemically processed fertilizers is very slow due to chemical fixation and perpetuation making 10 – 20% of applied 'P' available to the crops. This experiment is an approach to know the direct effect of phosphate rocks in an acidic environment to maize. Maize (*Zea mays* L.) is an important cereal food crop of the world with highest production and productivity as compared to rice and wheat. Maize is the third most important cereal after rice and wheat for human food by contributing almost 9% to India's food basket and 5% to World's dietary energy supply. Its production has increased more than 12 times from a mere 1.73 million tons 1950-51 to 21.73 million tons in 2014-17 and presently it occupies 8.55 million hectare area with the

mean yield of 9.0 tons/hectare. This achievement is remarkable despite ~75% maize area is under rainfed and low input condition, which often faces vagaries of monsoon. In India, it is being estimated that maize demand will continue to increase in view of increasing demand in poultry and livestock sectors in the country and growing non vegetarian population and changing food habits. To meet the growing demand, enhancement of maize yield in coming years across all the growing locations in India is the big challenge in the era of climate change. Meeting such challenge will only be possible through science based technological interventions like single cross hybrid technology and application of novel molecular tools and techniques in maize improvement.

### Materials and Methods

The field experiment entitled was conducted at central farm OUAT, Bhubaneswar under, Department of Soil Science & Agricultural Chemistry during Kharif 2017. The physiological studies were carried out in the Department of Plant Physiology, College of Agriculture, and Bhubaneswar. The experimental site is located in the Central Farm, OUAT, and Bhubaneswar which lies at 85° 47' 18" E latitude 20° 16' 51" N longitudes with an elevation of 25.9 meter above mean sea level. The summer months from March to May / June are hot and humid. The mean minimum and maximum temperature were 22.6 °C and 32.6 °C respectively. Temperatures drop December and January in approximately 15 °C during these months. The physico-chemical properties of the soil of experimental site were loamy texture with pH 5.2. The soil had the available Bray's P 15.68 kg ha<sup>-1</sup> (medium), Available Nitrogen 239 kg ha<sup>-1</sup>(low), Available Potassium 150 kg ha<sup>-1</sup> (medium) and Organic carbon 3.4 g kg<sup>-1</sup> Soil. Maize variety PAC-751 was taken for study and the experiment was laid out in a Randomised Block Design with 7 treatments and replicated thrice. All the treatments receives full dose of N and K as per the recommended dose of N:P:K (150:50:50) except control. For Maize P<sub>2</sub>O<sub>5</sub> was applied entirely as basal dose while N and K were applied as basal dose and as top dressing at sowing and tasseling stages respectively. Experimental Design and Treatments field experimental design laid out in Randomized Block Design with seven treatment T1 Control, T2 100% P(RP), T3 100% P(SSP), T4 75% P(RP) + 25% P(SSP), T5 50% P(RP) + 50% P(SSP), T6 25% P(RP) + 75% P(SSP) and T7 100% P(SSP) + Lime @ 0.2 LR and replicated in thrice times. Shoot dry matter and its partitioning at successive growth stages were calculated by taking two hills from each plot were randomly uprooted at heading and maturity stages for physiological observations. Plant parts such as stem, leaf and panicle were separated. The leaf area was measured by multiplying apparent leaf area (length and maximum breadth) with constant leaf area factor i.e., 0.725 at vegetative stage, 0.80 at maturity (Yoshida, 1981). The plant parts were dried separately in a hot air oven at 90°C for 48 hours. The dry weight of different plant parts was recorded at each growth stage and expressed in g/m<sup>2</sup>. Then it was ground to powder for further laboratory analysis. Growth Analysis parameters for example Leaf Area Index (LAI) is expressed as the ratio of the leaf area (A) (only one side) to the ground area (P) occupied by the crop (Watson, 1947)

$$LAI = A / P$$

Carbohydrate (NSC) content of plant samples was determined by following procedure (Yosidha *et al.*, 2005). 100 mg of

powdered dry sample was taken into in powder form and extracted using 80% ethanol (v/v). The extract was then used for sugar analysis by adding anthrone reagent, followed by measurement of absorbance at 630 nm using a spectrophotometre. in case of simple carbohydrate estimation the sample was kept in a boiling tube and hydrolyzed by keeping it in boiling water for three hours with 5 ml of 2.5 N HCl and then cooled to room temperature. The sample was neutralized with sodium carbonate till the effervescence ceases and then transferred it to 100ml volumetric flask and the volume was made up to 100 ml. 10ml of this was taken in a centrifuged tube and was centrifuged for 10 minute. The supernatant was collected and 0.2 to 0.3 aliquots were taken for analysis. 12 ml of anthrone reagent was added and heated for eight minutes in a boiling water bath. The absorbance (OD) of the filtrate was recorded at 630 nm. The quantity of glucose was calculated from the standard curve prepared from glucose stock solution.

Amount of carbohydrate present in 100 mg of the sample  

$$= \frac{[\text{mg sugar from grape/ml of aliquot sample}] \times (\text{Total volume of extract in ml of sample in mg})}{100}$$

The protein content was estimated by Lowry's method and TSS (Total soluble sugar) was estimated by anthrone reagent. The experimental design adopted for this research work was simple randomized block design (RBD).

## Results and Discussion

### Growth and morphological traits

**Plant Height:** Data on plant height of different maize hybrids grown under different doses of phosphorous application were recorded and presented in Table 1. The height increased progressively after planting and reached its maximum at harvest. Maximum increase evident during 30 DAS and slowly thereafter till harvest. T<sub>7</sub> (100% SSP + 0.2% LR) produced taller plants at harvest stage. Variation in plant height was found among the treatments. The maximum plant height of (63.95 cm) was recorded in T<sub>7</sub> followed by (57.33 cm) in T<sub>6</sub> at 30DAS and 225.83 cm in T<sub>7</sub> followed by (220.67cm) in T<sub>5</sub> at 90 DAS. Significant increase in height was recorded in plants supplied with 100% SSP+0.2% LR of recommended dose of phosphorous which was applied at sowing of the crop.

**Table 1:** Effect of different level of Phosphorous on Plant height

Treatment	30DAS	90DAS
T1 Control	49.82	187.33
T2 100% RP	52.13	193.67
T3 100% SSP	56.33	213.00
T4 75% RP+25% SSP	56.19	207.33
T5 50% SSP+50% RP	57.00	220.67
T6 25% RP+75% SSP	57.33	215.67
T7 100% SSP+0.2% LR	63.95	225.83
S.E.m(±)	1.338	1.338
C.D.(0.05)	1.124	1.124
C.V.	1.131	1.131

### Number of green leaves per plant

Data on number of green leaves per plant of maize hybrids grown under different doses of phosphorous were indicated in Table 2. The maximum number of green leaves per plant was produced in T<sub>7</sub> & T<sub>6</sub> at 30 DAS which were significantly at par with each other. Number of green leaves significantly increased from 30DAS to 90 DAS. The lowest no of leaves of 6.00 was recorded at T<sub>2</sub> over control at 30DAS and 7.00 at 90DAS. The highest number of leaves was recorded in T<sub>7</sub>. T<sub>5</sub> and T<sub>7</sub> was significantly at par with each other at 90DAS.

**Table 2:** No. of leaves per plant

Treatment	30DAS	90DAS
T1 Control	6.33	7.00
T2 100% RP	6.00	7.33
T3 100% SSP	7.0	9.33
T4 75% RP+25% SSP	6.33	8.33
T5 50% SSP+50% RP	6.67	10.33
T6 25% RP+75% SSP	7.33	10.0
T7 100% SSP+0.2% LR	7.33	11.33
S.E.m(±)	0.262	0.360
C.D.(0.05)	0.808	1.109
C.V.	6.766	6.856

### 3. Total dry matter production (g)

The dry matter production by maize increased progressively as the growth advanced and presented in (Table3). Maximum dry matter of 224.8 g plant<sup>-1</sup> was obtained from T<sub>7</sub> at 90DAS where as minimum dry matter accumulation (189.66 g /plant) was recorded by at 90 DAS. Application of different level of phosphorous also significantly influenced the total dry matter production at all the growth stages. At 30 DAS, the maximum dry matter production of 25.03 g plant<sup>-1</sup> was recorded in T<sub>7</sub> followed by 24.84 g plant<sup>-1</sup> in T<sub>6</sub>.

**Table 4:** Dry Weight After Harvest (G)

Treatment	30DAS	90DAS
T1	18.05	189.66
T2	18.81	201.28
T3	22.20	215.95
T4	21.64	204.02
T5	21.47	219.94
T6	24.84	218.94
T7	25.03	221.18
S.E.m(±)	0.808	2.589
C.D.(0.05)	2.489	7.976
C.V.	6.317	2.129

### Physiological Traits

#### LAI

Leaf area index (LAI) at both 30 DAS and 90 DAS were depicted in table- 5. Data on leaf area index of different Phosphorous management practice revealed that LAI increases from 30DAS to 90 DAS. LAI varied among the treatments. Maximum LAI among all the treatments was recorded in application of 100% SSP+0.2% LR (T<sub>7</sub>) followed by application of 25% RP+75% SSP (T<sub>6</sub>) at 90 DAS. The highest LAI was (1.75) in T<sub>7</sub> and lowest (1.33) over control in T<sub>1</sub> was recorded at 30 DAS. The highest LAI was (3.21) in T<sub>7</sub> followed by (3.00) in T<sub>5</sub> and lowest (1.97) in T<sub>2</sub> over control recorded was recorded at 90 DAS. Significant increase in LAI at both 30DAS and 90DAS were observed.

**Table 5:** LAI at 30 DAS and 90 DAS

Treatment	30DAS	90DAS
T1	1.30	1.84
T2	1.33	1.97
T3	1.64	2.64
T4	1.53	2.33
T5	1.67	3.00
T6	1.71	2.89
T7	1.75	3.21
S.E.m(±)	0.053	0.102
C.D.(0.05)	0.163	0.315
	5.984	6.944



**CGR, RGR and NAR**

Crop growth rate(CGR), Relative Growth Rate (RGR) and Net Assimilation Rate (NAR) determined between 30DAS to 90 DAS were depicted in table-6. CGR varied among the treatments ranging a minimum of 17.16 g/m<sup>2</sup>/day to a maximum of 19.93 g/m<sup>2</sup>/day. Among the treatments the highest CGR was recorded in T<sub>7</sub> where maize grown with 100% SSP+0.2% LR and the lowest CGR was recorded in T<sub>2</sub> over control. An increase in CGR was also observed with increase in availability of phosphorous. Significant increase in CGR was recorded at 100% SSP+0.2% LR (T<sub>7</sub>), 50% SSP (T<sub>3</sub>), 25% P (RP)+75% P (SSP) and 50% P (RP)+ 50% P (SSP) which were found at par. Significantly higher CGR were recorded in maize crop applied with 100% SSP+0.2% LR as compared the control. RGR increased with increase in level of Phosphorous availability to the plant. The lowest RGR (41.94 mg/g/day) was recorded in maize crop grown in(T<sub>2</sub>) over control and highest RGR (46.22 mg/g/day) was recorded in plants applied with 100% SSP+ 0.2% LR (T<sub>7</sub>) followed by 50% RP+50% SSP (T<sub>5</sub>). Among the combination of Rock Phosphate and Single Super Phosphate, T<sub>5</sub> registered the higher RGR than its sole application of 100% P (RP).

Net assimilation rate varied among the treatments ranging a minimum of 6.22 g/m<sup>2</sup>/day in T<sub>7</sub> to a maximum value of 9.33 g/m<sup>2</sup>/day in T<sub>1</sub>. Among the combined application of Rock Phosphate and SSP maximum NAR was recorded in single application of 100% P (RP) in T<sub>2</sub> and minimum NAR was recorded in 50% P (RP) + 50% P (SSP). T<sub>1</sub> and T<sub>2</sub>. Were significantly at par with each other.

**Table 6:** CGR, RGR and NAR

Treatment	CGR(g/m <sup>2</sup> /day) from 30-90 days	RGR (mg/g/day) from 30-90 days	NAR(g/m <sup>2</sup> /day)
T1	17.16	35.79	9.33
T2	18.24	41.94	9.31
T3	18.25	41.89	7.86
T4	19.37	42.62	7.37
T5	19.49	43.98	6.52
T6	19.45	41.38	6.78
T7	19.93	46.22	6.22
S.E.m(±)	0.250	0.675	0.279
C.D.(0.05)	0.771	2.080	0.859
C.V.	2.299	2.757	6.335

**Biochemical Analysis****Chlorophyll content**

The chlorophyll content of leaves was measured at 30DAS and at 90DAS and result was registered in (Table-7). From the data it was revealed that irrespective of treatments higher chlorophyll content recorded at 30DAS than at 90DAS. Maximum chlorophyll content was recorded in T<sub>5</sub> (50% RP+50% SSP) i.e. 2.95 mg/g of fresh weight followed by T<sub>7</sub> (100% SSP+0.2% LR) and minimum in T<sub>2</sub> at 30 DAS. Among the combined application of RP and SSP more chlorophyll content was found in T<sub>5</sub> followed by T<sub>6</sub> and minimum in T<sub>2</sub>. At 90DAS maximum value was found in T<sub>7</sub> (100% SSP + 0.2% LR) followed by T<sub>5</sub> (50% RP+50% SSP) and minimum in T<sub>2</sub> over control. At 90 DAS there was significant increase in chlorophyll content from maximum to minimum but significant difference was noticed in T<sub>5</sub> and T<sub>6</sub>.

**Table 7:** Chlorophyll Content

Treatment	At knee height	At harvest
T1	1.83	0.95
T2	2.31	1.10
T3	2.64	1.05
T4	2.62	1.10
T5	2.95	1.31
T6	2.75	1.20
T7	2.80	1.68
S.E.m(±)	0.130	0.060
C.D.(0.05)	0.400	0.186
C.V.	8.801	8.718

**Carbohydrate, Protein and Sugar% in Grain**

Carbohydrate, protein and sugar content in maize grain varied among the treatments. Irrespective of treatment the percent of carbohydrate is more as compared to protein than sugar represented in table-8. The lowest carbohydrate content (60.97%), was recorded in T<sub>2</sub> over control and the highest carbohydrate (65.29%) was recorded in T<sub>7</sub> (100% SSP + 0.2% LR) followed by T<sub>5</sub> (50% RP+50% SSP) of 61.37%. Carbohydrate content of grain significantly increased from highest in T<sub>7</sub> to lowest in T<sub>2</sub> value. But no significant difference was observed between T<sub>7</sub>, T<sub>6</sub>, T<sub>5</sub> & T<sub>3</sub>.

Protein content of grain differs significantly among the treatments. The lowest protein content (10.2%) was recorded in T<sub>2</sub> over control and the highest protein (11.0%) was recorded in T<sub>7</sub> (100% SSP + 0.2% LR) followed by T<sub>5</sub> (50% RP+50% SSP) of 10.53%. Protein content of grain significantly increased among all the treatments. Sugar content of T<sub>5</sub> and T<sub>7</sub> were significantly at par with each other. Maximum sugar content (1.20%) was recorded in T<sub>5</sub> followed by (4.00) in T<sub>7</sub>. The maximum sugar content of grain among the combination of RP and SSP, was recorded in T<sub>5</sub> followed by T<sub>6</sub>.

**Table 8:** Carbohydrate, protein and sugar content of grain in (%)

Treatment	Carbohydrate (%)	Protein(%)	Sugar(%)
T1	60.33	9.42	3.10
T2	60.97	10.20	3.17
T3	64.03	10.20	3.13
T4	62.33	10.07	3.53
T5	61.37	10.53	1.20
T6	63.04	10.43	3.73
T7	65.29	11.00	4.00
S.E.m(±)	0.839	0.149	0.096
C.D.(0.05)	2.586	0.460	0.296
C.V.	2.309	2.519	1.698

**Nutrient Content By shoot**

N, P and K content the shoot (Leaf & stem) and the seed was presented in table- 9. N content in plant was influenced by availability of Phosphorous in soil. The variation in N content in the plants varied among the treatments in the range of 0.69% to 1.40% in the shoot and 1.66 to 2.06% in grain respectively. The highest value of N was recorded in T<sub>7</sub>. N content in the stover and the grain increased with increase in level of Phosphate application but significant increase over control was recorded in T<sub>7</sub> (100% SSP + 0.2% LR) and T<sub>5</sub> (50% RP+50% SSP). However, no significant difference was

noticed in N content in the grain among the different combination of RP & SSP but significant difference was noticed N content in shoot. The content of P in the shoot and seed was influenced by the different levels of application of phosphorous. The variation recorded among the treatments for P concentration. was in the range of 0.37% to 0.55% in grain and 0.33% to 0.52% in maize Stover respectively. Among the treatments, the maximum P content in grain and Stover was found in T<sub>7</sub>. Among the combined application of RP and SSP T<sub>4</sub>, T<sub>5</sub> and T<sub>6</sub> were at par with each other. The K content varied among the treatments in the range of 1.19% to 1.81% in the grain and 0.45% to 0.73% in stover respectively. The highest K content was recorded in T<sub>7</sub>. Significant increase was recorded in plants supplied 100% SSP + 0.2% LR and 50% RP+50% SSP. There is no significant difference was recorded among the different combination of RP & SSP in the stover. Sulphur content of plant varied in stover and grain. In stover sulphur content varied from T<sub>1</sub> to T<sub>7</sub> significantly in the range of 1.19% to 1.8% minimum to maximum respectively. In stover the range varies from 0.45% to 0.73% minimum to maximum respectively.

#### Nutrient content of plant (%)

Nutrient content by plant and plant parts at harvest revealed that concentration of N, P and K was more by grain than stover and total uptake of N>K>P in all the treatments. Concentration of N, P and K by maize plant and its parts was influenced by the level of phosphorous application. Content of these three major nutrients increases with increase in level of P application but significant increase over control was observed was observed at 100% SSP+0.2% LR and 50% RP+50% SSP. Among the different combination of RP and SSP treatments the highest content of N, P and K in plant parts was recorded in maximum value was recorded in T<sub>5</sub> over the sole application of RP in Stover but in grain highest N, P & K content was recorded in T<sub>6</sub>. Sulphur content of plant varied in Stover and grain. In Stover sulphur content varied from T<sub>1</sub> to T<sub>7</sub> significantly Phosphorus is a component of nucleic acids and lipids and is important in the production and transport of sugars, fat and protein during sugar beet production. Phosphorus is especially important during early root development. A good supply of phosphorus ensures rapid root growth and good uptake of other nutrients, Masood *et al.* (2013). A good and optimum supply of P is associated with increased root growth due to which the plants explore more soil nutrients and moisture. That is why the grain yield was the lowest in the control plots because lack of P deteriorated the roots growth of the plants which negatively affected the other physiological functions of the maize plants in the control plots. Maqsood *et al.* (2013). Effect of phosphorus levels on the yield and yield components of maize. At harvest stage, the grain P content was much higher than that of the shoot. This may be due to the translocation of phosphorus from shoot to grain at the harvest stage (Hedley *et al.*, 1994). Uptake of all the macro and micronutrients increased with increasing P levels, indicating increase in dry weight of crop species with increasing P levels, Fageria *et al.*, (2013.) Sulfur (S) is a building block of protein and a key ingredient in the formation of chlorophyll. Crops cannot reach their full potential in terms of yield or protein contents without adequate sulfur (Zhao, 1999). Growth of maize is sensitive to sulfur deficiency because it decreases grain size under sulphur limiting condition. Sulfur has beneficial effects by lowering

soil pH and improving physical condition of the soil (Choudry and Das, 1996). Grain yield enhance with rising quantities of both sulfur and nitrogen and when soil is deficient in sulfur, full yield potential of the crop cannot be realized regardless of other nutrients (Tandon, 1984). The nutrition value of cereals is also determined by the proportion of S containing amino acids (Katyal, 1987). Phosphorus interacts with sulfur as phosphate ion is more strongly bond than sulphate (Hedge and Murthy, 2005). The application of phosphorous fertilizer results in increased anion adsorption sites, which releases sulphate ions into the solution (Tiwari and Gupta, 2006).

**Table 9:** Nutrient content in grain

Treatment	N%		P%		K%		S%	
	Grain	Stover	Grain	Stover	Grain	Stover	Grain	Stover
T1	1.66	0.69	0.37	0.60	0.63	0.33	1.19	0.45
T2	1.73	1.02	0.38	0.71	0.89	0.35	1.32	0.50
T3	1.84	1.30	0.51	0.93	1.02	0.37	1.59	0.61
T4	1.75	1.02	0.41	0.98	1.09	0.36	1.56	0.55
T5	1.96	1.30	0.49	1.09	0.97	0.44	1.64	0.61
T6	2.0	1.08	0.53	0.87	1.16	0.42	1.67	0.57
T7	2.06	1.40	0.55	1.17	1.33	0.52	1.81	0.73
S.E.m(±)	0.086	0.035	0.04	0.010	0.132	0.026	0.077	0.011
C.D.(0.05)	0.265	0.109	0.122	0.032	0.407	0.081	0.236	0.035
C.V.	8.014	5.465	15.338	11.117	16.182	11.468	8.638	3.372

#### Yield & Yield attributing characters

##### Yield attributing characters

Yield attributing characters were presented in table -10. Cob weight varied among the treatments. The highest cob weight (103.63g) was recorded in T<sub>7</sub> (100% SSP + 0.2% LR). Significant increase in cob weight was noticed among the other treatments. Number of grains per cob increased significantly with increase in application of different doses of phosphorous. Number of grains per cob was found highest in T<sub>7</sub> followed by T<sub>5</sub> differ significantly. Highest number of seed (103.6) was recorded in T<sub>7</sub> and lowest number of seed (81.4) was recorded in T<sub>2</sub> over control. Variation in number of row per cob was noticed among the treatments. The highest no. of row (18) was recorded in T<sub>7</sub> (100% SSP+0.2% LR) and lowest was (12) recorded in T<sub>4</sub>, T<sub>2</sub> and T<sub>1</sub>. Significant increase in no. of rows per cob was obtained with increase in the levels of application of P (SSP) applied. Different dose of Phosphorous significantly influenced the number of cob length presented in T<sub>7</sub> recorded the maximum mean cob length (24.93 cm) whereas T<sub>2</sub> had the minimum cob length (22.83cm) over control. Significant increase in cob length was recorded with the application of 100% SSP+0.2% (T<sub>7</sub>) LR followed by application of 50% RP+50% SSP (T<sub>5</sub>). No significant difference was recorded among the different combination of RP and SSP. Cob diameter varied significantly with regards to different dose of phosphorous application presented in (Table 4.). Application of 100% SSP+0.2% LR (T<sub>7</sub>) produced the thickest cob among all the treatments. T<sub>7</sub> recorded significantly thickest cob with diameter of 1.59cm followed by T<sub>3</sub> while T<sub>2</sub> produced the thinnest cob 1.2cm diameter over the control. Variation in 100 seed weight was noticed among the treatments. The highest test weight was (30.51g) and the lowest was (29.23g) were recorded in T<sub>7</sub> and T<sub>2</sub> respectively. Significant increase in test weight was obtained with increase in dose of P application but among the combined application of RP & SSP, T<sub>5</sub> and T<sub>6</sub> were significantly at par with each other.

**Table 10:** Yield and yield attributing characters

Treatment	Cob weight	No. of seeds per cob	No. of row per cob	Cob length	Cob diameter	100 seed weight
T1	67.72	415.33	12.00	20.65	1.16	24.90
T2	81.41	462.00	12.00	22.83	1.20	26.93
T3	94.98	481.67	14.00	23.37	1.57	28.17
T4	86.94	472.00	12.00	23.18	4.03	27.66
T5	97.6	526.33	16.00	23.90	1.34	29.33
T6	91.71	497.67	16.00	23.71	1.33	28.53
T7	103.63	530.67	18.00	24.93	1.59	30.51
S.E.m(±)	1.247	12.535	0.563	0.267	0.073	0.284
C.D.(0.05)	3.841	38.626	1.736	0.823	0.224	0.875
C.V.	2.411	1.489	6.831	1.992	2.915	1.757

### Harvest Index

Maize crop with different dose of phosphorous influenced the grain yield significantly presented in (Table 1.). Among the different treatments, T<sub>7</sub> recorded the highest yield (7.22 t ha<sup>-1</sup>) followed by T<sub>5</sub> (7.18 t ha<sup>-1</sup>) and were significantly at par with each other. The treatment T<sub>2</sub> recorded the minimum grain yield of 5.43 t ha<sup>-1</sup> over the control. The treatment T<sub>5</sub> and T<sub>6</sub> differ significantly among the different combination of RP and SSP. Harvest Index varied among the treatments. The highest HI (43.52%) was recorded in T<sub>7</sub> among the treatments. Increase in phosphorous dose significantly increased the HI in T<sub>7</sub> & T<sub>5</sub> respectively over the control. Among the combination of RP and SSP, T<sub>6</sub> and T<sub>5</sub> are significantly at par with each other.

**Table 11:** Harvest Index

Treatment	Yield (t/ha)	HI%
T1	4.75	31.14
T2	5.43	35.92
T3	6.52	40.37
T4	6.27	38.11
T5	7.18	42.31
T6	6.60	41.16
T7	7.26	43.52
S.E.m(±)	0.186	0.423
C.D.(0.05)	0.572	1.303
C.V.	5.113	1.861

**Table 12:** Correlation between growth and yield attributing characters with grain yield

Characters	Correlation co-efficient (r)
Plant height	0.943801
No.of leaves	0.90769
Dry weight	0.959966
LAI	0.909711
Chlorophyll	0.779848
Carbohydrate	0.916304
Protein	0.968037
Sugar	0.800878
Cob weight	0.999993
No. of Seeds per cob	0.903325
No.of row per cob	0.842295
Cob length	0.990181
Cob diameter	0.746024
100 seed weight	0.990118

### Correlation studies

Correlation studies were undertaken to determine the degree of association between yield and yield attributing characters of maize and the r values are presented in Table 12. The grain yield was positively correlated with all the yield attributing

characters. Growth characters viz., plant height at harvest, leaf area index at 60 DAS and dry matter accumulation were positively correlated with grain yield.

### References

1. Phosphorus Availability in Low-P and Acidic Soils as Affected by Liming and P Addition V. Antoniadis, F. Hatzis, D. Bachtsevanidis & S. D. Koutroubas; Communications in Soil Science and Plant Analysis. 2015; 46(10):1288-1298
2. Effect of Levels of Phosphorus and Sulphur on Growth, Yield and Quality of Sesame (*Sesamum indicum* L.) R I Shelke; N K Kalegore; K P Wayase World Journal of Agricultural Sciences. 2014; 10(3):108-111.
3. Radiation-Use Efficiency, Net Assimilation Rate and Thermal Integral as a Function of Phosphorus in Maize (*Zea mays* L.) DazLpez Ernesto; J Loeza Corte; EMorales Rosales Edgar J; DomnguezLpez Aurelio; FrancoMora Omar Agrociencia. 2013; 47(2):135-146.
4. Effect of Nitrogen and Phosphorous On Growth, Flowering, Fruiting and Yield of Tomato (*Lycopersicon esculentum* MILL.) M L Meena; K Ravendra; R B Ram; Progressive Horticulture. 2012; 44(2):727-739.
5. Supplementary Phosphorus can Alleviate Boron Toxicity in Tomato Cengiz Kaya; A Levent Tuna; M Dikilitas; A Muhhamed; Scientia Horticulturae. 2009; 121(3):284-288
6. Integrated Phosphorus Management in Maize (*Zea mays*)-Sunflower (*Helianthus annuus*)- Cowpea (*Vigna unguiculata*) Fodder Cropping System
7. Kumaresn MA, TN Balasubramanian Indian Journal of Agronomy, 2001, 46(3).
8. Establishment of the Critical Limit of Soil-Available Phosphorous for Maize Production in Low Acidic Ultisols of West Africa B V Bado; F Lompo; Communications in Soil Science and Plant Analysis. 2010; 41(8):968-976.
9. Crop (Maize) Response to Direct Application of Local Phosphate Rock on Selected Acid Soils of Tanzania; M M Msolla; J M R Semoka; C Szilas; Communications in Soil Science and Plant Analysis. 2007; 38(1-2):93-106.
10. Effect of Nitrogen and Phosphorous on Grain Yield of Hybrid Maize (*Zea mays* L.) M Yakadri; T Rmesh; B Vijay Kumar; Agricultural Science Digest, 2001, 21.