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Influence of phosphorus, sulphur and FYM on chemical composition of forage maize (*Zea mays* L.) grown on loamy sand soil

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Abstract

The pot experiment was carried out at the Net House of the Department of Soil Science and Agricultural Chemistry, B. A. College of Agriculture, Anand Agricultural University, Anand on the "Influence of phosphorus, sulphur and FYM on chemical composition of forage maize (*Zea Mays* L.) Grown on loamy sand soil" during summer season of the year 2017. The experiment was laid out in a completely randomized design (factorial) with three repetitions. The three levels of P_2O_5 (0, 30 and 60 kg ha^{-1}), three levels of S (0, 10 and 20 kg ha^{-1}) and two levels of FYM (0 and 10 t ha^{-1}) were tested in the experiment.
The P content in plant was significantly higher with application of P_2O_5 @ 60 kg ha^{-1} than rest of the levels at 30 DAS and harvest except P_2O_5 @ 30 kg P_2O_5 ha^{-1}. But N, K and S contents were not significantly influenced by application of phosphorus. Similarly S content was significantly higher under 20 kg ha^{-1} than control, but it was at par with 10 kg S ha^{-1}at 30 DAS and harvest. Application of FYM @ 10 t ha^{-1} recorded significantly higher N content at 30 DAS and at harvest than no FYM. All interaction effects of P, S and FYM were non- significant for nutrients content of plant at 30 DAS and harvest. The micronutrient (Fe, Mn, Zn and Cu) contents were not significantly modified by application of P, S and FYM. With regard to uptake, application of P_2O_5 @ 60 kg ha^{-1}, S @ 20 kg ha^{-1} and FYM @ 10 t ha^{-1} recorded significantly the highest uptake of N, P, K, S, Fe, Mn, Zn and Cu by crop at harvest.
Treatment combination of P_2O_5 @ 60 kg ha^{-1} along with S @ 20 kg ha^{-1} recorded significantly higher phosphorus, potassium, zinc and copper uptake by the crop than rest of the combinations except zinc and copper uptake, which were at par with all the levels of P and S for Zn and P_2O_5 @ 30 kg ha^{-1} + S @ 20 kg ha^{-1}combination for Cu. The interaction of P × F (P_2O_5 @ 60 kg ha^{-1} with FYM @ 10 t ha^{-1}) recorded significantly the highest uptake of P, K, S, Mn and Cu by maize. Similarly, the interaction effect of S × F (S @ 20 kg ha^{-1} with FYM @10 t ha^{-1}) recorded significantly the highest P and K uptake by maize. The interaction of P × S × F (P_2O_5 @ 60 kg ha^{-1} + S @ 20 kg ha^{-1} with FYM @ 10 t ha^{-1}) registered maximum values for P and K uptake, but P uptake was at par with $P_3S_2F_2$ (P_2O_5 @ 60 kg ha^{-1} + S @ 10 kg ha^{-1} along with FYM 10 t ha^{-1}) and K uptake was at par with $P_3S_2F_2$ (P_2O_5 @ 60 kg ha^{-1} + S @ 20 kg ha^{-1} along with FYM 10 t ha^{-1}), $P_3S_2F_1$(P_2O_5 @ 60 kg ha^{-1} + S @ 20 kg ha^{-1} along with FYM 0 t ha^{-1}) combinations.

Keywords: phosphorus, sulphur, FYM, forage maize, content and uptake

Introduction

Globally maize is cultivated in an area of 146 million hectare with a production of 680 million tonnes of grain with productivity of 4658 kg ha^{-1}. In India, maize ranks fifth in area and third in production and productivity among cereal crops with an area of 9.0 Mha. The important maize growing states in India are Punjab, Haryana, Uttar Pradesh, Madhya Pradesh, Bihar, Maharashtra, Rajasthan, Tamil Nadu, Gujarat, Andhra Pradesh and Jammu Kashmir. The area under maize crop in Gujarat is about 7800 ha. The average yield of green fodder maize is about 30 to 55 t ha^{-1} (Anon., 2014) [4]. Maize fodder contains relatively high concentration of soluble carbohydrates, crude protein content (8-9%), crude fiber content (30.2%) and ash content (6.6%). Maize crop can use extensively as a silage crop in both temperate and tropical climates because of its high biomass yield.

The production of maize is severely limited by P deficiency in tropical and subtropical agro climatic regions. This is in vogue for soils with high contents of iron or aluminium oxides to which P is strongly bound and thus is less available to plants. The maize and groundnut have various abilities to take up P from sparingly available forms such Al-P and Fe-P (Bhadoria *et al*, 2001) [6].

Phosphorus deficiency in Indian soils are wide spread (Bhandari, *et al*, 2004) [7]. Application of phosphorus has significant effect on grain and dry matter yields, number of leaves and leaf area (Ali, 2002 and Ayub, 2002) [3, 5].

In crop production, sometimes sulphur is considered to be forgotten secondary nutrient. However it is most essential for activity of proteolytic enzymes and synthesis of amino acids. If adequate supply of sulphur is ensured in the field it improves yield and quality of crops. The actual importance of sulphur has been noticed in the recent past due to exhaustive farming with high yielding varieties and the use of complex fertilizers, which led to sulphur deficiency in a lot of soils. Maize crop responds well to sulphur fertilization and it removes about 30-70 kg S ha^{-1}. Several workers have reported that uptake of major nutrients is also positively influenced by sulphur application (Bharathi and Poongothai, 2008) [8].

FYM is the source of primary, secondary and micronutrients, which are required for growth and development of crops. It is a constant source of energy for heterotrophic microorganisms, help in increasing the availability of nutrient and quality of crop produce. The entire amount of nutrients present in farmyard manure is not available immediately. About 30 per cent of nitrogen, 60 to 70 per cent of phosphorus and 70 per cent of potassium are available to the first crop. FYM improves soil physical properties like structure, water holding capacity etc. Carbon dioxide released during decomposition acts as a CO_2 fertilizer and plant parasitic nematodes and fungi are controlled to some extent by altering the balance of microorganisms in the soil.

Materials and Methods

A pot experiment was conducted during summer season of 2017 in the net house of the department of soil science and agricultural chemistry, Anand Agricultural University, Anand to carry out the study on "Influence of phosphorous, sulphur and FYM on chemical composition of forage maize (*Zea mays* L.) Grown on loamy sand soil". The materials used and methods adopted for the research works are described below.

1. Collection of soil and processing for experimentation

A bulk soil samples from a depth of 15 cm were collected from agriculture research station, Khambhodaj, AAU, Anand. The samples were collected by adopting selected randomly pits and composited. The composite samples were brought to the laboratory, air dried and powdered with a wooden hammer and used for pot study.

2. Description of soil under study

The soils were analyzed for their physico - chemical properties (Table 3.1). The soil collected from agriculture research station, Khambhodaj, AAU, Anand was of *Typic Ustochrepts*, having loamy sand soil texture, slightly alkaline in reaction (pH-8.05), whereas organic carbon contents, available N, S, Zn and Fe were low in status. While, the available K_2O and available P_2O_5 was medium in soil, whereas Mn and Cu contents were high in soil.

3. Pot culture study

A pot experiment was conducted to study the effect of levels of P, S and FYM on yield and chemical composition of maize (African tall) grown on a loamy sand soil. The details of the treatments were as under (Table 1).

Table 1: Experimental details

(i)	**Treatment details** (1) Phosphorus levels P_1 : 0 @ kg ha^{-1} P_2 : 30 @ kg ha^{-1} P_3 : 60 @ kg ha^{-1} (2) Sulphur levels S_1 : 0 @ kg ha^{-1} S_2 : 10 @ kg ha^{-1} S_3 : 20 @ kg ha^{-1} (3) FYM levels F_0 : FYM @ 0 t ha^{-1} F_1 : FYM @ 10 t ha^{-1}	
(ii)	Experimental design	CRD (factorial)
(iii)	Repetition	Three (03)
(iv)	Treatment combination	3 (P) × 3 (S) × 2 (FYM) = 18
(v)	Total no. of pots	18 × 3 = 54 pots
(vi)	Pot capacity	15 kg soil pot^{-1} (5 plants pot^{-1})
(vii)	Type of Soil	Loamy sand soil
(viii)	Crop and Variety	Maize (*Zea mays* L.), African-tall
(ix)	Date of sowing	05/03/2017
(x)	Date of harvesting	05/05/2017

The recommended dose of 80 kg N ha^{-1} applied as a urea, while phosphorus and sulphur applied as per treatment in the form of DAP and gypsum respectively, while FYM applied 10 days before sowing of the crop.

Farm yard manure (FYM)) used in experiment was analyzed for their N, P, K and micronutrient contents before incorporation into the soil. The results obtained are given below (Table 2).

Table 2: Chemical composition of FYM

Parameters	Values	Methods adopted	Reference
Total nitrogen content (%)	0.42	Kjeldahl's digestion method	(Jackson, 1973) [15]
Total phosphorus content (%)	0.38	Vanadomolybdo phosphoric acid yellow colour method	(Jackson,1973) [15]
Total potassium content (%)	0.43	Flame photometry	(Jackson, 1973) [15]

Total sulphur content (%)	0.04	Turbidimetric method	Sparks (1996) [31]
DTPA- Zn (mg kg^{-1})	136.8	Atomic Absorption Spectroscopy 0.005 M DTPA, pH 7.3	(Lindsay and Norvell, 1978) [31]
DTPA- Fe (mg kg^{-1})	658.0		
DTPA- Mn (mg kg^{-1})	232.2		
DTPA- Cu (mg kg^{-1})	89.4		

4. Chemical analysis of plant samples

Wet digestion procedure (Patiram *et al.* 2007) [26] was employed for preparation of acid extracts. The plant samples were analyzed for the following constituents as per the procedure given below.

Table 3: Methods for plant chemical analysis

S. No	Parameters	Methods	Reference
1.	Nitrogen (%)	Kjeldahl's Method	Jackson, 1973 [15]
2.	Phosphorus (%)	Vanadomolybdo phosphoric acid yellow colour	
3.	Potassium (%)	Flame photometric	
4.	Sulphur (%)	Turbidimetric method	Sparks (1996) [31]
5.	Iron, Manganese, Zinc, Copper (mg kg^{-1})	Atomic Absorption Spectrophotometry	Lindsay and Norvell (1978) [31]

5. Nutrient content and uptake

The major and secondary nutrients were expressed in percent while, micronutrients contents were expressed in ppm on oven dry weight basis. Nutrient uptake was calculated by using yield and nutrient content data. The uptake of these nutrients was computed by using the following formula.

For major and secondary nutrient

$$\text{Uptake (mg pot}^{-1}) = \frac{\text{Nutrient content (\%)} \times \text{Yield (g pot}^{-1}) \times 1000}{100}$$

For micronutrients

$$\text{Uptake (mg pot}^{-1}) = \frac{\text{Nutrient content (ppm)} \times \text{Yield (g pot}^{-1})}{1000}$$

Results and Discussion

Effect of p, s and FYM on chemical composition of maize

1. Effect on N, P, K and S Content at 30 DAS

The data on N, P, K and S content in forage maize at 30 DAS are presented in Table 4.

Table 4: Influence of phosphorus, sulphur and FYM on N, P, K and S content in forage maize at 30 DAS

Treatments	Nutrients content (%)			
	N	P	K	S
[A] Phosphorus levels:				
P_1: 0 kg ha^{-1}	2.20	0.231	0.904	0.165
P_2: 30 kg ha^{-1}	2.22	0.235	0.927	0.169
P_3 : 60 kg ha^{-1}	2.28	0.239	0.938	0.180
S.Em ±	0.04	0.002	0.011	0.005
C.D. (0.05)	NS	0.006	NS	NS
[B] Sulphur levels:				
S_1 : 0 kg ha^{-1}	2.19	0.232	0.93	0.159
S_2 : 10 kg ha^{-1}	2.28	0.235	0.931	0.168
S_3 : 20 kg ha^{-1}	2.23	0.239	0.935	0.186
S.Em ±	0.04	0.002	0.011	0.005
C.D. (0.05)	NS	NS	NS	0.014
[C] FYM levels:				
F_1 : 0 t ha^{-1}	2.17	0.234	0.914	0.170
F_2 : 10 t ha^{-1}	2.30	0.236	0.932	0.172
S.Em ±	0.03	0.002	0.009	0.004
C.D. (0.05)	0.08	NS	NS	NS
[D] Interaction				
P×S	NS	NS	NS	NS
P×F	NS	NS	NS	NS
S×F	NS	NS	NS	NS
P×S×F	NS	NS	NS	NS
CV %	6.70	3.6	4.89	12.35

1.1 Effect of phosphorus

The application of different levels of P had significant influence on P content in forage maize. While its effect was non-significant on N, K and S content in forage maize. Data given in Table 4 clearly indicated that significantly the higher P content (0.239%) was found with P_3 (60 kg P_2O_5 ha^{-1}) over control and at par with P_2 (30 kg P_2O_5 ha^{-1}).

1.2 Effect of sulphur

It was observed from the data presented in Table 4 that N, P and K content found to be not significant due to application of sulphur. However, it was observed that application increasing rate of S increased the S content in forage maize. Significantly the highest S content (0.186%) was found with S_3 (20 kg S ha^{-1}) over rest of the treatments. Sulphate is highly mobile in the soil and reaches the plant roots quickly. The application of sulphur during an early stage and during intensive plant growth makes it suitable for more adsorbed by plant hence increased in S content in plant that reported by Kayser, 2000 [19]. These findings are in accordance with the finding of Karimizarchi *et al.* (2016) [17], Muhammad *et al.* (2006) [23] and Bharathi *et al.* (2008) [8] in maize.

1.3 Effect of FYM

It was revealed from the data presented in Table 4 that N content at 30 DAS found significant while P, K and S content found non-significant influence by application of FYM. Significantly the highest N content (2.30%) was found with F_2 (10 t FYM ha^{-1}) over control treatment.

Karki *et al.* (2005) [18], Totawat *et al.* (2001) [32] and Prasad *et al.* (2010) [28] also noted that the application of FYM @ 10 t ha^{-1}increased N content in plant.

1.4 Interaction effect

The interaction effect of P, S and FYM was found to be non-significant on plant content of N, P, K and S at 30 DAS of maize.

2. Effect on N, P, K and S Content at Harvest

The data on N, P, K and S content in maize at harvest are presented in Table 5.

2.1 Effect of phosphorus

The data tabulated in the Table 5 revealed that the P content was significantly increased due to increased application of P, whereas N, K and S content were not-significant at harvest of maize. This results were in line with resulted noticed by

Chaudhary *et al.* (2003) [9], Roy *et al.* (2010) [30] and Polat *et al.* (2007) [27].

2.2 Effect of sulphur

The perusal of data given in Table 5 indicated the S application was non- significantly influenced on N, P and K content at harvest. Significantly higher S content (0.167%) was found with S_3 (20 kg S ha^{-1}) over control treatment, but at par with S_2 (10 kg S ha^{-1}) level. Similar results also found by Jaggi and Raina (2008) [16], Muhammad *et al.* (2006) [23] and Abdul *et al.* (2016) [1].

Table 5: Influence of phosphorus, sulphur and FYM on N, P, K and S content in forage maize at harvest

Treatments	Nutrients content (%)			
	N	P	K	S
[A] P levels:				
P_1 : 0 kg ha^{-1}	1.20	0.161	1.12	0.157
P_2 : 30 kg ha^{-1}	1.23	0.164	1.15	0.159
P_3 : 60 kg ha^{-1}	1.24	0.167	1.16	0.160
S.Em ±	0.01	0.002	0.01	0.004
C.D. (0.05)	NS	0.004	NS	NS
[B] S levels:				
S_1 : 0 kg ha^{-1}	1.20	0.162	1.15	0.148
S_2 : 10 kg ha^{-1}	1.22	0.164	1.13	0.160
S_3 : 20 kg ha^{-1}	1.24	0.166	1.15	0.167
S.Em ±	0.01	0.002	0.01	0.004
C.D. (0.05)	NS	NS	NS	0.011
[C] FYM levels:				
F_1 : 0 t ha^{-1}	1.19	0.162	1.14	0.156
F_2 : 10 t ha^{-1}	1.26	0.165	1.15	0.160
S.Em ±	0.01	0.001	0.01	0.003
C.D. (0.05)	0.03	NS	NS	NS
[D] Interaction				
P×S	NS	NS	NS	NS
P×F	NS	NS	NS	NS
S×F	NS	NS	NS	NS
P×S×F	NS	NS	NS	NS
CV %	4.30	3.90	3.12	10.61

2.3 Effect of FYM

From the data presented in Table 5 revealed that N content at harvest found significant, while and P, K and S content found non-significant by application of FYM. The significantly the highest N content (1.26%) was found with F_2 (10 t FYM ha^{-1}) over control treatment.

2.4 Interaction effect

The interaction effect of P, S and FYM was found to be non-significant on plant content of N, P, K and S at harvest of maize.

3 Effect on Micronutrients (Fe, Mn, Zn and Cu) Content at 30 DAS and at Harvest

The data pertaining in Table 6 and 7 showed that the influence of P, S and FYM was found non-significant effect on Fe, Mn, Zn and Cu content in forage maize.

3.1 Effect of phosphorus, sulphur, FYM and Interaction effect

The data given in Table 6 and clearly indicate that the phosphorus, sulphur, FYM and interaction treatments was found non-significant on plant content of Fe, Mn, Zn and Cu at 30 DAS and at harvest.

Table 6: Influence of phosphorus, sulphur and FYM on micronutrients content in forage maize at 30 DAS

Treatments	Micronutrients content (mg kg^{-1})			
	Fe	Mn	Zn	Cu
[A] Phosphorus levels:				
P_1 : 0 kg ha^{-1}	262.61	21.13	23.65	6.09
P_2: 30 kg ha^{-1}	263.95	21.41	22.41	6.16
P_3 : 60 kg ha^{-1}	263.31	21.68	22.02	6.13
S.Em ±	2.97	0.47	0.54	0.06
C.D. (0.05)	NS	NS	NS	NS
[B] Sulphur levels:				
S_1 : 0 kg ha^{-1}	263	20.97	22.11	6.04
S_2 : 10 kg ha^{-1}	265.28	21.63	22.63	6.14
S_3 : 20 kg ha^{-1}	261.60	21.63	23.17	6.20
S.Em ±	2.97	0.47	0.54	0.06
C.D. (0.05)	NS	NS	NS	NS
[C] FYM levels:				
F_1 : 0 t ha^{-1}	260	20.91	22.03	6.07
F_2 : 10 t ha^{-1}	266.54	21.91	23.28	6.18
S.Em ±	2.42	0.38	0.44	0.05
C.D. (0.05)	NS	NS	NS	NS
[D] Interaction				
P×S	NS	NS	NS	NS
P×F	NS	NS	NS	NS
S×F	NS	NS	NS	NS
P×S×F	NS	NS	NS	NS
CV %	4.78	9.22	10.1	3.87

Table 7: Influence of P, S and FYM on micronutrients content in forage maize at harvest

Treatments	Micronutrients content (mg kg^{-1})			
	Fe	Mn	Zn	Cu
[A] Phosphorus levels:				
P_1 : 0 kg ha^{-1}	251.68	17.34	25.19	5.25
P_2: 30 kg ha^{-1}	252.39	17.47	24.78	5.34
P_3 : 60 kg ha^{-1}	251.16	17.84	23.89	5.25
S.Em ±	3.18	0.37	0.53	0.06
C.D. (0.05)	NS	NS	NS	NS
[B] Sulphur levels:				
S_1 : 0 kg ha^{-1}	252.06	17.28	23.68	5.17
S_2 : 10 kg ha^{-1}	252.19	17.63	25.28	5.36
S_3 : 20 kg ha^{-1}	250.26	17.73	24.90	5.30
S.Em ±	3.18	0.37	0.53	0.06
C.D. (0.05)	NS	NS	NS	NS
[C] FYM levels:				
F_1 : 0 t ha^{-1}	248.29	17.30	24.03	5.23
F_2 : 10 t ha^{-1}	255.20	17.80	25.20	5.33
S.Em ±	2.59	0.30	0.43	0.05
C.D. (0.05)	NS	NS	NS	NS
[D] Interaction				
P×S	NS	NS	NS	NS
P×F	NS	NS	NS	NS
S×F	NS	NS	NS	NS
P×S×F	NS	NS	NS	NS
CV %	5.35	8.94	9.09	5.12

4. Effect on N, P, K and S uptake by plant at harvest

Data regarding the nutrient uptake of nitrogen, phosphorus, potassium and Sulphur by maize as influenced by different levels of P, S and FYM are presented in Table 8.

4.1 Effect of phosphorus

From the data presented in Table 8, it was found that an application of 60 kg P_2O_5 ha^{-1} (P_3) registered significantly the highest nitrogen (717.77 mg pot^{-1}), phosphorus (96.46 mg pot^{-1}), potassium (668.29 mg pot^{-1}) and sulphur (93.44 mg pot^{-1}) uptake by maize, over rest of the treatments.

Table 8: Influence of phosphorus, sulphur and FYM on N, P, K and S uptake by forage maize at harvest

Treatments	Major and S Nutrients Uptake (mg pot^{-1})			
	N	P	K	S
[A] Phosphorus levels:				
P_1 : 0 kg ha^{-1}	585.00	78.31	543.47	76.42
P_2: 30 kg ha^{-1}	623.20	83.40	586.30	80.82
P_3 : 60 kg ha^{-1}	717.77	96.46	668.29	93.44
S.Em ±	18.02	2.21	14.79	3.08
C.D. (0.05)	51.68	6.35	42.42	8.83
[B] Sulphur levels:				
S_1 : 0 kg ha^{-1}	527.35	70.85	503.95	64.93
S_2 : 10 kg ha^{-1}	644.31	86.78	600.17	84.72
S_3 : 20 kg ha^{-1}	754.31	100.54	693.94	101.03
S.Em ±	18.02	2.21	14.79	3.08
C.D. (0.05)	51.68	6.35	42.42	8.83
[C] FYM levels:				
F_1 : 0 t ha^{-1}	571.66	78.03	546.94	75.80
F_2 : 10 t ha^{-1}	712.32	94.09	651.77	91.32
S.Em ±	14.71	1.81	12.08	2.51
C.D. (0.05)	42.20	5.19	34.64	7.21
[D] Interaction				
P×S	NS	Sig.	Sig.	NS
P×F	NS	Sig.	Sig.	Sig.
S×F	NS	Sig.	Sig.	NS
P×S×F	NS	Sig.	Sig.	NS
CV %	11.90	10.91	10.46	15.63

4.2 Effect of sulphur

The data pertaining given in Table 8 indicated the sulphur treatment had significant influence on uptake of N, P, K and S at harvest. Significantly the highest uptake of 754.31, 100.54, 693.94 and 101.03 mg pot^{-1} N, P, K and S was found with S_3 (20 kg S ha^{-1}) over the rest of treatments, respectively.

Increased levels of sulphur progressively enhanced the nutrient uptake by maize, which can be attributed to proportionate increase in dry matter production and nutrient content. This might be due to higher dry matter production as well as higher nutrient content at this level. This result were also concealed by Choudhary *et al.* (2013) [11], Mehta *et al.* (2005) [22] and Rahman *et al.* (2011) [29].

4.3 Effect of FYM

The perusal of data given in Table 8 indicated the differences in nutrient uptake of N, P, K and S due to application of FYM. Significantly the highest uptake of N (712.32 mg pot^{-1}), P (94.09 mg pot^{-1}), K (651.77mg pot^{-1}) and S (91.32 mg pot^{-1}) were found with application of FYM @ 10 t ha^{-1} (F_2).

4.4 Interaction effect

The different interaction effect among phosphorus, sulphur and FYM was found non-significant in case of N uptake by maize. While P X S, P X F, S X F, P X S X F interaction was found significant in respect to P and K uptake by maize. The P X F was also significantly affected the S uptake by maize (Table 8a, 8b, 8c, 8d, 8e, 8f, 8g, 8h and 8i).

4.4.1 Effect of P × S interaction

The significantly higher P uptake (109.98 mg pot^{-1}) was observed with the application of 60 kg P_2O_5 ha^{-1} along with 20 kg S ha^{-1} (P_3S_3), but it was at par with P_2S_3 (30 kg P_2O_5 ha^{-1} + 20 kg S ha^{-1}) and P_3S_2 (60 kg P_2O_5 ha^{-1} + 10 kg S ha^{-1}) (Table 8a). Perusal of data given in Table 8b showed that treatment combination of P_3S_3 (60 kg P_2O_5 ha^{-1} + 20 kg S ha^{-1}) recorded significantly higher K uptake (773.94 mg pot^{-1}) by maize than rest of the combinations.

Combine effect of Phosphorus and sulphur found positive effect on P and K uptake might be due to application of nutrients particularly P and S in right proportion might have lead to balance development of vegetative portion of the plant which required higher consumption of P and K in fodder crop which ultimately increase uptake of P and K in maize (Irfan *et al.* 2015) [14]. This same result reported by Patel *et al.* (2003) [25], Muhammad *et al.* (2015) [24] and Imran *et al.* (2014) [13].

Table 8a: Interaction effect of phosphorus and sulphur on phosphorus (mg pot^{-1}) uptake by forage maize at harvest

Treatments	S_1 (0 kg ha^{-1})	S_2 (10 kg ha^{-1})	S_3 (20 kg ha^{-1})
P_1 (0 kg ha^{-1})	66.86	76.20	91.86
P_2 (30 kg ha^{-1})	72.54	77.91	99.76
P_3 (60 kg ha^{-1})	73.16	106.24	109.98
S.Em ±	3.84		
C.D. at 5 %	10.99		
C.V. %	10.91		

Table 8b: Interaction effect of phosphorus and Sulphur on potassium uptake (mg pot^{-1}) by forage maize at harvest

Treatments	S_1 (0 kg ha^{-1})	S_2 (10 kg ha^{-1})	S_3 (20 kg ha^{-1})
P_1 (0 kg ha^{-1})	486.59	534.56	609.25
P_2 (30 kg ha^{-1})	508.31	551.97	698.64
P_3 (60 kg ha^{-1})	516.94	713.98	773.94
S.Em ±	25.61		
C.D. at 5 %	73.47		
C.V. %	10.46		

4.4.2 Effect of P × F interaction

The data pertaining in Table 8c clearly indicated the interaction of P × F was affected significantly on uptake of P by maize. Significantly the highest uptake of P (108.67 mg pot^{-1}) was observed due to 60 kg P_2O_5 ha^{-1} along with 10 t FYM ha^{-1} (P_3F_2) over rest of the combinations. The data given in Table 8d clearly indicated the highest uptake of K (746.85 mg pot^{-1}) was observed due to 60 kg P_2O_5 ha^{-1} along with 10 t FYM ha^{-1} (P_3F_2) over rest of the combinations.

Table 8c: Interaction effect of phosphorus and FYM on phosphorus uptake (mg pot^{-1}) by forage maize at harvest

Treatments	F_1 (0 t ha^{-1})	F_2 (10 t ha^{-1})
P_1 (0 kg ha^{-1})	75.85	80.77
P_2 (30 kg ha^{-1})	73.98	92.83
P_3 (60 kg ha^{-1})	84.25	108.67
S.Em ±	3.13	
C.D. at 5 %	8.98	
C.V. %	10.91	

Table 8d: Interaction effect of phosphorus and FYM on potassium uptake (mg pot^{-1}) by forage maize at harvest

Treatments	F_1 (0 t ha^{-1})	F_2 (10 t ha^{-1})
P_1 (0 kg ha^{-1})	528.55	558.38
P_2 (30 kg ha^{-1})	522.53	650.08
P_3 (60 kg ha^{-1})	589.73	746.85
S.Em ±	20.91	
C.D. at 5 %	59.99	
C.V. %	10.46	

Table 8e: Interaction effect of phosphorus and FYM on Sulphur uptake (mg pot^{-1}) by forage maize at harvest

Treatments	F_1 (0 t ha^{-1})	F_2 (10 t ha^{-1})
P_1 (0 kg ha^{-1})	74.54	78.30
P_2 (30 kg ha^{-1})	73.57	88.08
P_3 (60 kg ha^{-1})	79.30	107.58
S.Em ±	4.35	
C.D. at 5 %	12.49	
C.V. %	15.63	

The data pertaining in Table 8e clearly indicated the interaction of P × F was affected significantly on uptake of S by maize. Significantly the highest uptake of S (107.58 mg pot^{-1}) was observed due to 60 kg P_2O_5 ha^{-1} along with 10 t FYM ha^{-1} (P_3F_2) over rest of the combinations.

The application of phosphorus along with FYM increased nutrients uptake by maize. This might be probably due to increase in better utilization of plant nutrients from the soil which in turn increased crop yield. Further, because of these nutrients are present in FYM and hence addition of FYM along with phosphorus would have enriched the soil with them and there by enhanced the uptake of nutrients by maize crop (Zerihun *et al.*, 2013) [36]. The phosphorus application also improves the root growth which has a great effect on the overall plant growth performance. This result also reported by Ademba *et al.* (2015) [2] and Venkatesh *et al.* (2002) [34].

4.4.3 Effect of S × F interaction

The data pertaining in Table 8f clearly indicated the interaction of S × F was affected significantly on uptake of P by maize. Significantly the highest uptake of P (111.79 mg pot^{-1}) was observed due to 20 kg S ha^{-1} along with 10 t FYM ha^{-1} (S_3F_2) over rest of the combinations.

Similarly, the interaction of S × F was affected significantly on uptake of K by maize (Table 8g). Significantly the highest uptake of K (754.93 mg pot^{-1}) was observed due to 20 kg S ha^{-1} along with 10 t FYM ha^{-1} (S_3F_2) over rest of the combinations.

Table 8f: Interaction effect of sulphur and FYM on phosphorus uptake (mg pot^{-1}) by forage maize at harvest

Treatments	F_1 (0 t ha^{-1})	F_2 (10 t ha^{-1})
S_1 (0 kg ha^{-1})	67.49	74.21
S_2 (10 kg ha^{-1})	77.31	96.26
S_3 (20 kg ha^{-1})	89.28	111.79
S.Em ±	3.13	
C.D. at 5 %	8.98	
C.V. %	10.91	

Table 8g: Interaction effect of sulphur and FYM on potassium uptake (mg pot^{-1}) by forage maize at harvest

Treatments	F_1 (0 t ha^{-1})	F_2 (10 t ha^{-1})
S_1 (0 kg ha^{-1})	482.03	525.86
S_2 (10 kg ha^{-1})	525.82	674.52
S_3 (20 kg ha^{-1})	632.96	754.93
S.Em ±	20.91	
C.D. at 5 %	59.98	
C.V. %	10.46	

Application of S significantly increased the S uptake by maize. This increase in S uptake may be attributed to increase in S concentration in plant and dry matter yield. This might be probably due to increase in better utilization of plant nutrients from the soil which in turn increased crop yield. Further, because of these nutrients are present in FYM and hence addition of FYM would have enriched the soil with them and there by enhanced the uptake of nutrients by maize crop. The similar result found by Chaudhary (2008) [10].

4.4.4 Effect of P × S × F interaction

The data pertaining in Table 8h clearly indicated the interaction of P × S × F was affected significantly on uptake of P by maize. Significantly higher uptake of P (119.31 mg pot^{-1}) was observed due to 60 kg P_2O_5 + 20 kg S ha^{-1} along with 10 t FYM ha^{-1} ($P_3S_3F_2$) over rest of the combinations. This result was at par with $P_3S_2F_2$ and $P_2S_3F_2$ treatment combinations.

The data pertaining in Table 8i clearly indicated the interaction of P × S × F was affected significantly on uptake of K by maize. Significantly the higher uptake of K (822.36 mg pot^{-1}) was observed due to application 60 kg P_2O_5 + 10 kg S ha^{-1} along with 10 t FYM ha^{-1} ($P_3S_2F_2$) over rest of the combinations and at par with $P_3S_3F_1$, $P_3S_3F_2$ and $P_2S_3F_2$ treatments.

Table 4.7h: Interaction effect of phosphorus, sulphur and FYM on phosphorus uptake (mg pot^{-1}) by forage maize at harvest

SF/P	S_1 (0 kg ha^{-1})		S_2 (10 kg ha^{-1})		S_3 (20 kg ha^{-1})	
	F_1(0 t ha^{-1})	F_2(10 t ha^{-1})	F_1(0 t ha^{-1})	F_2(10t ha^{-1})	F_1(0 t ha^{-1})	F_2(10 t ha^{-1})
P_1 (0 kg ha^{-1})	71.39	62.32	71.63	80.76	84.57	99.21
P_2 (30 kg ha^{-1})	73.10	71.98	66.16	89.65	82.66	116.85
P_3 (60 kg ha^{-1})	57.98	88.33	94.12	118.36	100.64	119.31
S.Em ±	5.42					
C.D. at 5 %	15.56					
C.V. %	10.91					

Table 4.7i: Interaction effect of phosphorus, sulphur and FYM on potassium uptake (mg pot^{-1}) by forage maize at harvest

SF/P	S_1 (0 kg ha^{-1})		S_2 (10 kg ha^{-1})		S_3 (20 kg ha^{-1})	
	F_1(0 t ha^{-1})	F_2 (10 t ha^{-1})	F_1 (0 t ha^{-1})	F_2 (10 t ha^{-1})	F_1(0 t ha^{-1})	F_2(10 t ha^{-1})
P_1 (0 kg ha^{-1})	509.06	464.13	492.69	576.43	583.90	634.59
P_2 (30 kg ha^{-1})	511.64	504.96	479.17	624.75	576.71	820.50
P_3 (60 kg ha^{-1})	425.38	608.49	605.59	822.36	738.19	809.70
S.Em ±	36.22					
C.D. at 5 %	104.00					
C.V. %	10.46					

4.5 Effect on micronutrients (Fe, Mn, Zn and Cu) Uptake by Plant at Harvest

Micronutrients uptake of Fe, Mn, Zn and Cu by maize at harvest were significantly influenced by different levels of P, S and FYM (Table 9).

4.5.1 Effect of phosphorus

The data given in Table 9 showed that the uptake of Fe, Mn, Zn and Cu at harvest significantly influenced by different levels of phosphorus.

Significantly the highest uptake of Fe (14.48 mg pot^{-1}), Mn (1.03 mg pot^{-1}) and Cu (0.30mg pot^{-1}) were found with application of P_3 (60 kg P_2O_5 ha^{-1}) over the rest of treatments.

Whereas, application of 60 kg P_2O_5 ha^{-1}(P_3) gave significantly higher Zn (1.39 mg pot^{-1}) uptake by maize over rest of treatments.

4.5.2 Effect of sulphur

The data presenting in Table 9 indicated the sulphur treatment had significant influence on uptake of Fe, Mn, Zn and Cu at harvest.

Significantly the highest uptake of Fe (15.20 mg pot^{-1}), Mn (1.07 mg pot^{-1}), Zn (1.51 mg pot^{-1}) and Cu (0.32mg pot^{-1}) was found with S_3 (20 kg S ha^{-1}) over the rest of treatments.

Table 9: Influence of phosphorus, Sulphur and FYM on micronutrients uptake by forage maize at harvest

Treatments	Micronutrients uptake (mg pot^{-1})			
	Fe	Mn	Zn	Cu
[A] Phosphorus levels:				
P_1 : 0 kg ha^{-1}	12.23	0.84	1.23	0.25
P_2: 30 kg ha^{-1}	12.84	0.89	1.26	0.27
P_3 :60 kg ha^{-1}	14.48	1.03	1.39	0.30
S.Em ±	0.39	0.03	0.04	0.01
C.D. (0.05)	1.12	0.08	0.13	0.02
[B] Sulphur levels:				
S_1 : 0 kg ha^{-1}	11.02	0.76	1.04	0.23
S_2 :10 kg ha^{-1}	13.33	0.93	1.33	0.28
S_3 :20 kg ha^{-1}	15.20	1.07	1.51	0.32
S.Em ±	0.39	0.03	0.04	0.01
C.D. (0.05)	1.12	0.08	0.13	0.02
[C] FYM levels:				
F_1 : 0 t ha^{-1}	11.91	0.83	1.16	0.25
F_2 : 10 t ha^{-1}	14.46	1.01	1.43	0.30
S.Em ±	0.32	0.02	0.04	0.01
C.D. (0.05)	0.92	0.06	0.10	0.02
[D] Interaction				
P×S	NS	NS	Sig.	Sig.
P×F	NS	Sig.	NS	Sig.
S×F	NS	NS	NS	NS
P×S×F	NS	NS	NS	NS
CV %	12.61	12.17	14.43	11.73

The oxidation process of sulphur take place in the soil when S is added to the soil. During the oxidation of S, acid is released which leads to soil acidity and decreased soil pH and with the decreasing in pH of soil the micronutrients availability is increased therefore ultimately leads to increase the uptake of micronutrients (Clement 1978). This result also found by Khin (2007).

4.5.3 Effect of FYM

A perusal of data (Table 9) revealed that micronutrients uptake of Fe, Mn, Zn and Cu at harvest by maize was significantly influenced due to application of FYM.

The application of FYM @ 10 t ha^{-1} (F_2) recorded significantly the highest nutrient uptake of Fe (14.46 mg pot^{-1}), Mn (1.01 mg pot^{-1}), Zn (1.43 mg pot^{-1}) and Cu (0.30 mg pot^{-1}) by maize at harvest as compared to no application of FYM (F_1).

4.5.4 Interaction effect

The different interaction effect among phosphorus, sulphur and FYM was found non-significant in case of Fe uptake by maize. While P × S interaction was found significant in case of Cu and Zn uptake. While P × F interaction were found significant in case of and Mn and Cu uptake by maize.

4.5.4.1 Effect of P × S interaction

The significantly higher zinc uptake (1.60 mg pot^{-1}) was observed with the application of 60 kg P_2O_5 ha^{-1} along with 20 kg S ha^{-1} (P_3S_3). The significantly higher copper uptake (0.352 mg pot^{-1}) was observed with the application of 60 kg P_2O_5 ha^{-1} along with 20 kg S ha^{-1} (P_3S_3). The increased micronutrients uptake with combined application P and S might be due to increased root growth, which resulted in better exploration of soil volume (Yadav *et al.* 2012) [35]. Results were in conformity with the findings of Yadav *et al.* (2012) [35], Muhammad *et al.* (2015) [24] and Patel *et al.* (2003) [25].

Table 9a: Interaction effect of phosphorus and sulphur on zinc uptake (mg pot^{-1}) by forage maize at harvest

Treatments	S_1 (0 kg ha^{-1})	S_2 (10 kg ha^{-1})	S_3 (20 kg ha^{-1})
P_1 (0 kg ha^{-1})	1.05	1.20	1.44
P_2 (30 kg ha^{-1})	1.06	1.22	1.50
P_3 (60 kg ha^{-1})	0.99	1.59	1.60
S.Em ±	0.07		
C.D. at 5 %	0.22		
C.V. %	14.43		

Table 9b: Interaction effect of phosphorus and sulphur on copper uptake (mg pot^{-1}) by forage maize at harvest

Treatments	S_1 (0 kg ha^{-1})	S_2 (10 kg ha^{-1})	S_3 (20 kg ha^{-1})
P_1 (0 kg ha^{-1})	0.225	0.252	0.288
P_2 (30 kg ha^{-1})	0.228	0.262	0.322
P_3 (60 kg ha^{-1})	0.227	0.337	0.352
S.Em ±	0.01		
C.D. at 5 %	0.03		
C.V. %	11.73		

4.5.4.2 Effect of P × F interaction

The significantly highest Mn and Cu uptake (1.18 and 0.348 mg pot^{-1}) was observed with the application of 60 kg P_2O_5 ha^{-1} along with 10 t FYM ha^{-1} (P_3F_2) (Table 9c and 9d). Incorporation of FYM along with inorganic P increased the availability of micronutrients and this was attributed to reduction in fixation of micronutrient, increased mineralization of organic matter due to microbial action and enhanced availability of nutrients (Varalakshmi *et al.*, 2005) [33].

Table 9c: Interaction effect of phosphorus and FYM on Mn uptake (mg pot^{-1}) by forage maize at harvest

Treatments	F_1 (0 t ha^{-1})	F_2 (10 t ha^{-1})
P_1 (0 kg ha^{-1})	0.799	0.874
P_2 (30 kg ha^{-1})	0.803	0.976
P_3 (60 kg ha^{-1})	0.876	1.18
S.Em ±	0.03	
C.D. at 5 %	0.10	
C.V. %	12.17	

Table 9d: Interaction effect of phosphorus and FYM on Cu uptake (mg pot^{-1}) by forage maize at harvest

Treatments	F_1 (0 t ha^{-1})	F_2 (10 t ha^{-1})
P_1 (0 kg ha^{-1})	0.246	0.264
P_2 (30 kg ha^{-1})	0.249	0.292
P_3 (60 kg ha^{-1})	0.262	0.348
S.Em ±	0.01	
C.D. at 5 %	0.03	
C.V. %	11.73	

Conclusion

The results of the present investigation revealed that application of phosphorus @ 60 kg ha^{-1} + sulphur @ 20 kg ha^{-1} along with FYM 10 t ha^{-1} resulted in increased nutrient content and uptake by forage maize.

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