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Response of Growth of Quality Protein Maize (QPM) as Influenced by Sulphur Levels and Method of Application

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ABSTRACT

A field experiment was conducted to study the effect of different levels and two methods of sulphur application on growth parameters of quality protein maize (QPM) at College farm, Professor Jayashankar Telangana State Agricultural University, Hyderabad, during 2014-2015 using factorial randomized block design (FRBD) with three replications and eight combinations as four different sulphur levels (10 kg ha^{-1}, 20 kg ha^{-1}, 30 kg ha^{-1} and 40 kg ha^{-1}) and two methods of sulphur application (M_1: 100% basal as single dose; M_2: Two split applications: 50% each at basal and knee heigh stage). Maximum plant height, LAI and Dry matter production was obtained with 40 kg S ha^{-1} as compared to 30 kg S ha^{-1}, 20 kg S ha^{-1} and 10 kg S ha^{-1}. Similarly, two methods of application split application of sulphur at basal and knee heigh stage shown maximum plant height, LAI and Dry matter production. Almost all the treatments have significantly affected in 60 DAS, 90 DAS and harvest stage of plant height, LAI, Dry matter production but 30 DAS is shown no significant. Plant population and days to 50% flowering has shown no significant effect. Application of sulphur at 40 kg ha^{-1} along with split method of application can be recommended for sustaining productivity and profitability in quality protein maize. The right quantity and application at correct stage of the plant is important for growth and development of QPM.

Introduction

Maize is considered a promising option for diversifying agriculture in areas of India. It now ranks as the third most important food grain crop in India. The maize area has slowly expanded over the past few years and predicted that this area would grow further to meet future food, feed, and other demands, especially in view of the booming livestock and poultry producing sectors in the country.

To minimize prevalence and persistence of malnutrition in developing countries, when modified to produce a vitreous endosperm resembling that of Conventional Maize, maize that contains approximately double the amount of lysine and tryptophan has been named as “quality protein maize” (QPM). QPM is a cheap source of protein, given that farmers can grow, manage, harvest and consume it in the same way they do Conventional Maize varieties (Vasal, 1999).

Maize is an exhaustive crop and absorbs huge quantity of nutrient from the soil during different stages of growth. Sulphur is an essential nutrient for animal and all plant life. Generally, plants require about a tenth as much sulphur (S) as nitrogen (N), but sulphur deficiencies restrict plant growth as surely and severely as nitrogen deficiencies. It is well known that sulphur is a vital macro element in plant growth. Sulphur is a macro element in plant growth and increases the absorption of micronutrients by pH decreasing. Plant takes up approximately the same amount of sulphur as that of phosphorus (Tandon, 1991).

Sulphur importance is increasing in all regions of the world and in some areas is second to nitrogen in importance (Muhammad, 1994). Sulphur deficiencies are occurring with greater frequency in more locations throughout the world. As a result of its importance many agriculturists are now classifying it as fourth major nutrient. Sulphur plays a vital role in the primary metabolism of higher plants and involved in synthesis of secondary metabolic products in certain groups of plants (Lakkineni and Abrol, 1994) which can have an impact on photosynthesis and grain quality. In the soil, sulphur can exist in many organic and inorganic forms, although plants only take up sulphur in the divalent anion form ($SO_4^{\ 2-}$) (Patil *et al.*, 1998).

Some of the nitrogen is applied before planting and the rest between tillering and jointing. No similar recommendations exist for sulphur. Since sulphate is an anion similar to nitrate, would a split application of sulphur be beneficial over a single broadcast application to maintain a soil sulphur concentration that is adequate to maximize crop growth and yields and increase grain protein content when sulphur levels are deficient recently, so that a research project is proposed to examine an investigation on different sulphur levels and methods of application (basal and split method of application) on growth and growth parameters of quality protein maize crop.

Materials and Methods

The experiment was laid out at college farm of Professor Jayashankar Telangana State Agricultural University, Rajendranagar, Hyderabad during *kharif* season 2014-2015 to study performance of growth of Quality Protein Maize (QPM) as influenced by Sulphur levels and Method of application. The soil of the experimental field was sandy loam in texture, neutral in reaction, low in organic carbon, available nitrogen and sulphur, medium in available phosphorous and high in potassium. Experiment was carried out with four sulphur levels (S_1: 10 kg ha^{-1}, S_2: 20 kg ha^{-1}, S_3: 30 kg ha^{-1} and S_4: 40 kg ha^{-1}) as first factor and method of sulphur application (M_1: 100% basal as single dose; M_2: Two split applications:-50% each at basal and knee heigh stage) as second factor comprising eight treatment combination, laid out in randomized block design with factorial concept replicated thrice. Quality protein maize hybrid (HQPM-1) was sown in *kharif*-2014 at a spacing of 60 cm x 20 cm. A uniform dose of 80 kg P_2O_5 as diammonium phosphate, potassium at 80 kg ha^{-1} as murate of potash was applied to all the treatments. Entire dose of phosphorous and half of potassium were applied at the time of sowing. Nitrogen was applied as per the treatments through urea in three equal splits (at basal, knee-heigh and tasseling stages). Similarly the remaining potassium and nitrogen was top dressed at tasseling stage. Sulphur was applied through gypsum in two methods of applications i.e.M_1- 100% basal application at time of sowing; M_2- two split applications:- 50% each at basal and knee heigh stage as per the treatments.

Results and Discussion

Growth parameters

Plant population

Results revealed that there was no significant variation in plant stand due to either sulphur levels or method of application. However, on an average 3.2% of plant population reduction was noticed from initial to final plant population. The results on initial and final plant population of quality protein maize as influenced by sulphur levels and method of application are presented in table 1.

Plant height

The results of plant height of quality protein maize at all crop growth stages as influenced by sulphur levels and method of application are presented in table 2. As the crop aged from 30 to 90 DAS, the plant height increased progressively with sulphur levels and method of application, but showed declining rate of increase at harvest. At 30 DAS with increase in sulphur application from 10 to 40 kg ha^{-1}, The plant height linearly increased, and reached to maximum with 40 kg ha^{-1} (51.8 cm) and minimum with 10 kg S ha^{-1} (40.3 cm). Among the method of application, the plant height was found to be non-significant.

Among the four sulphur levels 40 kg S ha^{-1} (S_4) had recorded significantly maximum plant height (170 cm) at 60 DAS, followed by 30 kg ha^{-1}(161.5 cm) and least plant height of 146.8 cm with 10 kg S ha^{-1} (S_1). Within the two method of application, split application as basal and at knee heigh stage had resulted in taller plants of 159.6 cm compared to basal application (155.7 cm) of sulphur and this difference was statistically significant. As the crop advanced to 90 DAS significantly taller plants were noticed with application of 40 kg S ha^{-1} (189 cm), followed by 30 kg ha^{-1} (178.3 cm), and minimum plant height of 163.4 cm was recorded with 10 kg sulphur application. Split application of sulphur at basal and knee heigh stage (M_2) had shown significantly more plant height of 177.7 cm over that of only (M_1) basal method of application (173.1 cm).

There was only marginal increase of plant height by the time crop reached harvest stage compared to 90 DAS, where 40 kg S ha^{-1} had shown plant height of 194.4 cm, followed by 30 kg ha^{-1} (182.5 cm). Least plant height of 166.4 cm was noticed due to application of 10 kg S ha^{-1}. Likewise, split application of sulphur both as basal and at knee heigh stage of the crop (M_2) produced taller plants at harvest stage (181.6 cm) compared to that of total amount of sulphur as basal application (M_1) (176.9 cm).

Interaction effect between levels and method of application of sulphur was found to be non-significant with the plant height of quality protein maize hybrid at all stages of the crop growth. Higher levels of sulphur dose increased plant height of maize plants, which may be attributed to multiple role of sulphur in protein and carbohydrate metabolism, activating many enzymes which influences photosynthesis and shoot length.

These results are in line with the findings of Dhananjay (1998), Bhagyalakshmi *et al.* (2010) and Choudhary *et al*., (2013). Adequate sulphur supply in split doses might have resulted in better utilization of sulphur to synthesize more carbohydrates to form more protoplasm, cell division, leaf expansion and improved vegetative growth of the plant which is in accordance with the results of Ahmad *et al*., (1998).

Leaf Area Index (LAI)

The results on LAI of quality protein maize at different crop growth stages as influenced by sulphur levels and method of application are presented in table 3. LAI was significantly influenced by sulphur levels and method of application. Increasing sulphur levels from 10 to 40 kg ha^{-1} progressively improved leaf area index of quality protein maize from 30, 60, 90 DAS and up to harvest stage.

Leaf area index of maize crop was significantly influenced by sulphur levels at 30 DAS. Among the four sulphur levels higher LAI was observed with S_4 (1.61), followed by S_3 (1.41) and S_2 (1.21), while lowest LAI of 1.03 was recorded with S_1. LAI of crop was not influenced due to method of application of sulphur at early stages of crop growth. Similarly, at 60 DAS, significantly maximum LAI (3.76) was observed with 40 kg S ha^{-1}. Minimum LAI of 3.18 was noticed when maize crop was fertilized with 10 kg sulphur application. Split application of sulphur at basal and at knee heigh stage (M_2) resulted in maximum leaf area index (3.59) followed by conventional method of application (3.33) (M_1) and this difference were statistically significant. The data at 90 DAS on LAI revealed that, as the crop advanced to 90 days, the LAI increased progressively with sulphur levels. Among the four sulphur levels, significantly higher LAI of 4.53 was observed with 40 kg S ha^{-1}, over that of obtained with 30 kg ha^{-1} (4.23), 20 kg S ha^{-1} (3.91), while the least leaf area index was shown when was maize fertilized with 10 kg S ha^{-1} (3.68). In method of sulphur application, the LAI was found significantly superior in split application as 50% basal and 50% at knee heigh stage (4.28) compared to 100% basal application (3.90).

At harvest, as the crop reached maturity and with senescence irrespective of the treatments, the LAI decreased compared to 30, 60 and 90 DAS. However, even at harvest, 40 kg S ha^{-1} had resulted in higher LAI of 3.66 which was significantly. Superior over all other lower rates of sulphur application, split application of sulphur as basal and at knee heigh stage (M_2) recorded higher LAI of 3.54 while lower LAI (3.15) was seen with maize when sulphur was applied basally (M_1).

Interaction effect between levels and method of application of sulphur was non-significant with regard to LAI of quality protein maize hybrid at all growth stages. Leaf area index is an important plant index determining the capacity of plants in trapping solar energy for photosynthesis. Progressive increase in LAI was due to increased sulphur application, which increased nutrient uptake thereby enhancing rate of photosynthesis and leaf expansion. These results are similar to the findings of Khan *et al.*, (2005) Daniela *et al.*, (2008) and Tanveer *et al*., (2013). Application of the entire amount of sulphur in a single basal dose may not meet the increased demand for sulphur during crop growth, and results in a rapid decline in leaf area index due to increased senescence of the leaves. Hence split application of sulphur leads to better leaf area expansion, which helped in subsequent interception and efficient utilization of solar radiation. These findings were supported by Ahmad *et al*., 2005; Saeed *et al*., 2015.

Dry matter production (kg ha^{-1})

Results regarding dry matter production revealed that it was significantly influenced by sulphur levels and method of application at all stages of crop growth i.e. from 30 DAS up to harvest which is presented in table 4. Perusal of data indicates that at 30 DAS, dry matter production was significantly influenced by sulphur levels. Among the four sulphur levels the dry matter production was significantly higher (5215 kg ha^{-1}) with 40 kg S ha^{-1}, followed by 30 kg ha^{-1} (4855 kg ha^{-1}) and 20 kg S ha^{-1} (4365 kg ha^{-1}). Lower dry matter production of 4026 kg ha^{-1} was obtained by maize crop when applied with 10 kg sulphur application. Among the method of sulphur application, the dry matter production was found to be non-significant. Among the four sulphur levels, the data at 60 DAS indicates that 40 kg S ha^{-1} had given significantly higher dry matter production (8990 kg ha^{-1}) followed by 30 kg S ha^{-1} (8585 kg ha^{-1}). Sulphur when fertilized with 10 kg ha^{-1} had produced the plants with the least dry matter production of 7709 kg ha^{-1} at 60 days after sowing. Within the two method of application, split application (M_2) of sulphur as 50% as basal and 50% at knee heigh stage had resulted in more dry matter production (8513 kg ha^{-1}) compared to 100% basal application (8202 kg ha^{-1}) i.e. (M_1). As the crop advanced to 90 DAS, the dry matter production increased progressively with sulphur levels and method of application. The four levels of sulphur significantly influenced the dry matter production at 90 DAS, where maximum dry matter production of 12116 kg ha^{-1} was noticed with 40 kg S ha^{-1} which was significantly superior over the dry matter production obtained with 30 kg S ha^{-1} (11640 kg ha^{-1}), followed by 20 kg ha^{-1} (11021 kg ha^{-1}). 10 kg S ha^{-1} had produced the least dry matter production of 10558 kg ha^{-1} compared with other levels.

Application of sulphur in split dose both as basal and at knee heigh stage (M_2) had shown higher dry matter production of 11540 kg ha^{-1} significantly superior to conventional method of sulphur application (11127 kg ha^{-1}) (M_1).

Table.1 Initial and final population (000 ha^{-1}) of QPM as influenced by sulphur levels and method of application

	Initial population			**Final population**		
Sulphur levels (S)	**Basal (M_1)**	**Split (M_2)**	**Mean**	**Basal (M_1)**	**Split (M_2)**	**Mean**
S_1 : 10 kg ha^{-1}	79.61	81.09	80.35	78.28	78.09	78.18
S_2 : 20 kg ha^{-1}	81.20	81.44	81.32	78.20	78.78	78.49
S_3 : 30 kg ha^{-1}	81.30	81.86	81.58	78.63	79.20	78.91
S_4 : 40 kg ha^{-1}	81.33	82.53	81.93	77.66	80.86	79.26
Mean	80.86	81.73		78.19	79.23	
	SEm±	CD (p=0.05)		SEm±	CD (p=0.05)	
S	0.83	NS		1.05	NS	
M	0.58	NS		0.74	NS	
S x M	1.17	NS		1.48	NS	

M_1: 100% basal application; M_2: 50% basal+50% at knee heigh stage

Table.2 Plant height (cm) of QPM as influenced by sulphur levels and method of application

	30DAS			60DAS			90DAS			At Harvest		
Sulphur levels (S)	**Basal (M_1)**	**Split (M_2)**	**Mean**	**Basal (M_1)**	**Split (M_2)**	**Mean**	**Basal (M_1)**	**Split (M_2)**	**Mean**	**Basal (M_1)**	**Split (M_2)**	**Mean**
S_1 : 10 kg ha^{-1}	39.2	41.4	40.3	145.2	148.4	146.8	161.8	165.0	163.4	164.5	168.4	166.4
S_2 : 20 kg ha^{-1}	43.5	45.7	44.6	151.0	153.7	152.4	168.6	173.2	170.5	169.9	177.6	173.7
S_3 : 30 kg ha^{-1}	47.2	49.9	48.5	158.7	164.2	161.5	174.5	182.2	178.3	179.8	185.2	182.5
S_4 : 40 kg ha^{-1}	50.8	52.9	51.8	168.0	172.0	170.0	187.7	190.4	189.0	193.4	195.4	194.4
Mean	45.2	47.4		155.7	159.6		173.1	177.7		176.9	181.6	
	SEm±	CD (p=0.05)		SEm±	CD (p=0.05)		SEm±	CD (p=0.05)		SEm±	CD (p=0.05)	
S	1.15	3.33		1.73	4.90		1.94	5.55		2.08	6.03	
M	0.81	NS		1.22	3.46		1.37	3.92		1.47	4.26	
S x M	1.71	NS		2.45	NS		2.74	NS		2.94	NS	

M_1: 100% basal application; M_2: 50% basal+50% at knee heigh stage

Table.3 Leaf area index (LAI) of QPM as influenced by sulphur levels and method of application

	30DAS			60DAS			90DAS			At Harvest		
Sulphur levels (S)	**Basal (M_1)**	**Split (M_2)**	**Mean**	**Basal (M_1)**	**Split (M_2)**	**Mean**	**Basal (M_1)**	**Split (M_2)**	**Mean**	**Basal (M_1)**	**Split (M_2)**	**Mean**
S_1 : 10 kg ha^{-1}	1.00	1.06	1.03	3.10	3.26	3.18	3.53	3.83	3.68	2.93	3.20	3.06
S_2 : 20 kg ha^{-1}	1.23	1.20	1.21	3.13	3.53	3.33	3.73	4.10	3.91	3.10	3.33	3.21
S_3 : 30 kg ha^{-1}	1.30	1.53	1.41	3.40	3.73	3.56	4.00	4.46	4.23	3.20	3.70	3.45
S_4 : 40 kg ha^{-1}	1.50	1.73	1.61	3.70	3.83	3.76	4.33	4.73	4.53	3.40	3.93	3.66
Mean	1.25	1.38		3.33	3.59		3.90	4.28		3.15	3.54	
	SEm±	CD (p=0.05)		SEm±	CD (p=0.05)		SEm±	CD (p=0.05)		SEm±	CD (p=0.05)	
S	0.06	0.18		0.07	0.20		0.10	0.29		0.07	0.20	
M	0.04	NS		0.04	0.11		0.07	0.20		0.05	0.14	
S x M	0.09	NS		0.09	NS		0.15	NS		0.10	NS	

M_1: 100% basal application; M_2: 50% basal+50% at knee heigh stage

Table.4 Dry matter production (kg ha-1) of QPM as influenced by sulphur levels and method of application

	30DAS			**60DAS**			**90DAS**			**At Harvest**		
Sulphur levels (S)	**Basal (M_1)**	**Split (M_2)**	**Mean**	**Basal (M_1)**	**Split (M_2)**	**Mean**	**Basal (M_1)**	**Split (M_2)**	**Mean**	**Basal (M_1)**	**Split (M_2)**	**Mean**
S_1 : 10 kg ha^{-1}	3883	4168	4026	7563	7856	7709	10378	10739	10558	10512	10839	10675
S_2 : 20 kg ha^{-1}	4225	4506	4365	7978	8314	8146	10880	11162	11021	10987	11269	11128
S_3 : 30 kg ha^{-1}	4791	4919	4855	8395	8775	8585	11416	11864	11640	11520	11981	11750
S_4 : 40 kg ha^{-1}	5167	5264	5215	8872	9108	8990	11836	12396	12116	11937	12500	12218
Mean	4516	4714		8202	8513		11127	11540		11239	11647	
	SEm±	CD (p=0.05)		SEm±	CD (p=0.05)		SEm±	CD (p=0.05)		SEm±	CD (p=0.05)	
S	106	309		135	391		150	436		153	448	
M	75	NS		96	278		106	308		108	316	
S x M	151	NS		192	NS		212	NS		216	NS	

M_1: 100% basal application; M_2: 50% basal+50% at knee heigh stage

Table.5 Days to 50% flowering of QPM as influenced by sulphur levels and method of application

	Days to 50% tasseling			**Days to 50% silking**		
Sulphur levels (S)	**Basal (M_1)**	**Split (M_2)**	**Mean**	**Basal (M_1)**	**Split (M_2)**	**Mean**
S_1 : 10 kg ha^{-1}	51.0	51.6	51.3	54.0	54.6	54.3
S_2 : 20 kg ha^{-1}	52.6	53.0	52.8	55.3	56.3	55.8
S_3 : 30 kg ha^{-1}	54.0	54.4	54.2	57.0	57.6	57.3
S_4 : 40 kg ha^{-1}	54.6	57.0	55.8	58.3	60.0	59.1
Mean	53.0	54.0		56.1	57.1	
	SEm±	CD (p=0.05)		SEm±	CD (p=0.05)	
S	0.46	1.35		0.49	1.44	
M	0.32	NS		0.35	NS	
S x M	0.65	NS		0.70	NS	

M_1: 100% basal application; M_2: 50% basal+50% at knee heigh stage

As the crop reached the harvest stage there was only marginal increase of dry matter production compared to 90 DAS. Sulphur applied at 40 kg ha^{-1} had shown higher dry matter production of 12218 kg ha^{-1}, followed by 30 kg ha^{-1} (11750 kg ha^{-1}). Least dry matter production of 10675 kg ha^{-1} was noticed with 10 kg S ha^{-1}. Split application of sulphur as basal and at knee heigh stage (M_2) had reported maximum dry matter production at harvest stage (11647 kg ha^{-1}) compared to basal application of sulphur applied (11239 kg ha^{-1}) (M_1).

Interaction effect between levels and method of application of sulphur was found non-significant on the dry matter production of quality protein maize hybrid. The larger photosynthetic area and prolonged photosynthesis due to leaf area index and number of leaves per plant lead to higher dry matter production because of higher and balanced supply of sulphur fertilizers. Kochar *et al.*, (1990), Srinivasrao *et al.*, (2010) and Nanthakumar *et al.*, (2014) also noticed higher dry matter production in maize due to positive effects of sulphur. Split application of sulphur at vegetative stage resulted in higher biomass accumulation due to production of more photosynthates. These results also confirm the findings of Havlin *et al.*, (2004) and Wang *et al.*, (2014).

Days to 50% flowering

Results (Table 5) revealed that days to 50 % flowering was significantly influenced by sulphur levels and while method of application had not shown any significant effect. Among the four levels of sulphur, days to 50% tasseling was delayed when maize was fertilized with highest dose of sulphur at 40 kg ha^{-1} (55.8 days), and 54.2 days with 30 kg S ha^{-1} and 52.8 days in maize crop fertilized with 20 kg S ha^{-1}. It was observed that tasseling occurred earlier 51.3

days when maize was fertilized with 10 kg S ha^{-1}. Days to 50% Silking was delayed (59.1 days) when maize was applied with highest dose of sulphur of 40 kg ha^{-1}, followed by 57.3 days with 30 kg S ha^{-1}. It was observed that silking was attained earlier 54.3 days when maize was applied with 10 kg S ha^{-1}.

The days to 50% tasseling and silking were not influenced by method of sulphur application i.e. 100% basal application (M_1) and split application (M_2) (50% as basal+ 50% at knee heigh stage). Combined effect of sulphur levels and method of sulphur application was non- significant with regard to days to 50% flowering. The abundant supply of fertilizers to the crop will promote vegetative growth for long duration, there by delaying flowering compared to the treatments where quality protein maize was supplied with less or without fertilizers, which attained flowering earlier. These results are in accordance with the findings of Kumar, 2008, Ali *et al*., (2013) and Rani *et al.*, (2013).

In conclusion, Based on the results obtained in this investigation it can be concluded that, out of four levels of sulphur and two methods of sulphur application tested, in levels 40 kg sulphur ha^{-1} and split application in basal and knee heigh stage was ideal for increasing the growth and growth parameters of the quality protein maize crop. So our results suggested that using the different levels of sulphur along with split application provide sulphur to the crop during the entire period of its growth and development.

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