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Days to Silking, Stover Yield and Soil Electrical Conductivity of Maize Hybrid -Babar As Affected by Nitrogen and Sulfur Applied in Different Combinations

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Abstract

Maize is the 2nd important crop after wheat in Khyber Pakhtunkhwa. It needs greater amount of nutrients particularly nitrogen (N) and sulfur (S). Application of N and S at different growth stages enhances growth and yield of maize. Therefore, its effect in various ratios needs to be quantified on maize hybrid Babar. Four N levels (120, 160, 200, 240 kg ha^{-1}), four S levels (20, 25, 30, 35 kg ha^{-1}) applied in three ratios R1 (10:50:40), R2 (20:50:30) and R3 (30:50:20) i.e. 10, 20 and 30 % of required N and S were applied at sowing, 50% of required N and S were applied at V8, while 40, 30 and 20% of required N and S were applied at tasseling stage in R1, R2 and R3, ratios respectively. Combinations of all these treatments along with control were assessed in two year field experiments at Agronomy, Research Farm, The University of Agriculture Peshawar Pakistan. N, S and control vs. fertilized significantly affected days to silking (DTS), stover yield (SY) and soil electrical conductivity (EC) over the years, whereas days to 50% emergence (DTE) were non-significantly affected. Delayed DTS (66 days) were observed with application of 240 kg N ha^{-1}, 30 kg S ha^{-1}, 30:50:20 ratio of N and S application. Highest SY (7147 kg ha^{-1}) was observed with application of 240 kg N ha^{-1}, 35 kg S ha^{-1}, R3 (30:50:20). Maximum soil EC (0.246 d S m^{-1}) was observed with 240 kg N ha^{-1}, 30 kg S ha^{-1}, 30:50:20 ratio of N and S application. Application of 200 kg N ha^{-1}, 35 kg S ha^{-1}, R3 (30:50:20) performed better than other treatments and is recommended for obtaining higher yield of maize hybrid Babar in Peshawar valley.

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Introduction

Maize (*Zea mays* L.) is the third most important cereal in the world and Pakistan, while in Khyber Pakhtunkhwa it ranks second after wheat. Maize occupies an area of 1059 thousand hectares in Pakistan, producing 4220.1 thousand tons of maize with an average yield of 3983 kg ha^{-1} (MINFAL, 2009). In Khyber Pakhtunkhwa, maize covers an area of 463.4 thousand hectares producing 858.3 thousand tons with an average yield of 1852 kg ha^{-1} (MINFAL, 2009).

The average yield of maize in Pakistan is tremendously low compared with other maize producing countries of the world. Mismanagement of plant nutrition is considered to be the major cause of low yield. Hence there is a need to improve this major component of the production technology for obtaining higher maize yield. Balanced fertilization is an essential component of nutrient management and plays a significant role in enhancing crops yield and quality (Sawyer and Mallarino, 2007). N is the motor of plant growth and makes up 1 to 4 percent of dry matter of the plants (Randhawa *et al.,* 2000).

Nitrogen is a component of protein and nucleic acids and hence it is needed in high quantities. N deficiency causes reduction in growth and development of maize. N stress at any growth stage during maize plant's life reduce yield (Ciampitti *et al.,* 2010). Maize requires only a fraction of this N during the seedling stage, but N needs escalate rapidly once maize reaches the V8 growth stage (collar of 8th leaf is visible). Maize can grow to shoulder height (approximately V8 to V14) in about two weeks, and reach the tassel / silking stage (VT/R1) in about two more weeks.

This rapid growth requires a large supply of N to fulfill the demands of prolific green tissue development. Maize takes up half of its N supply between V8 and VT (Shanahan *et al.*, 2011).

Nitrogen also plays a crucial role in ear and kernel development. N translocation within the plant indicates that N moves to the ear from other plant tissues even before silking for kernel embryo formation (Ciampitti and Vyn, 2010). Continued ear growth and yield accumulation is closely associated with N content in the above ground plant tissues. Continued N uptake during the ear-fill period can minimize the remobilization of N from vegetative to reproductive tissues.

This allows the plant to retain more green leaf area, which increases the duration of photosynthesis, carbohydrate production and grain yield (Randall and Schmitt, 2004).

Sulfur is an essential plant nutrient for crop production. Amount of S required to produce one ton of seed is about 3-4 kg S for cereals and 8 kg S for legume crops. In intensive crop rotations, S uptake can be very high, especially when the crop residue is removed from the field along with the product. This leads to considerable S depletion in soil (Jamal *et al.*, 2009).

Sulfur is best known for its role in the formation of amino acids methionine (21% S) and cysteine (27% S); synthesis of proteins and chlorophyll; oil content of the seeds and nutritive quality of forages (Jamal *et al.*, 2009) An insufficient S supply reduces yield and quality and is a constituent of the amino acids, methionine and cysteine (Jamal *et al.*, 2010) .Full yield potential of the crop cannot be achieved regardless of other nutrients if S is deficient (Rasheed *et al.*, 2003). For some enzymes, disulfide bond formation serves to regulate activity. Many enzyme

s of carbon dioxide fixation are regulated in this way. The regulatory molecule in this case is thioredoxin, which reduces target enzymes using electrons from ferredoxin. Particular conditions, such as low organic matter content in soils, soil erosion and high nutrient removal by crops may determine S deficiency in crops (Scherer *et al.*, 2009).

S applied with N increases yield over control in cereals. Higher yield can be explained by hormonal effect of S through increased methionine in the vegetative tissues. This amino acid (methionine) is a recognized precursor in the biosynthesis of ethylene, one of the regulatory hormones of plant growth (Garcia *et al.,* 1999). N and S supply are interdependent. The requirement of one depends on the supply of the other, and the imbalance in their supply causes a reduction in the yield because of reduced uptake and assimilation of the two nutrients. Sulfur should be applied in split doses, along with N (Ahmad *et al.*, 1998) .The aim of this study is to analyze the effects of different N and S and their interaction on silking, stover yield of hybrid maize Babar and soil EC.

Materials and methods

Site description

The experimental site, new developmental farm, the University of Agriculture Peshawar, Pakistan is located at 34° N and 71.3° E at an altitude of 350 m above sea level, 1600 km north of Indian Ocean with a sub-tropical, sub-humid and continental climate. Mean daily maximum (summer) temperature ranges from 40 to 44 °C and minimum (winter) temperature drops down to 4 °C. Annual rainfall varies from 450 to 750 mm with about 60% in summer months.

Soil analysis

Ten composite soil samples at 0–30 cm depths were taken from the experimental field before planting and after harvest of maize from each plot in 2011 and 2013. Soil samples were bulked and analyzed for soil texture (Ahmad *et al.*, 1998), soil pH (McClean *et al.,*1982)., soil electrical conductivity (Black *et al.,*1965)., soil organic matter (Nelson *et al.,*1982) and soil total nitrogen (Bremner *et al.,* 1982).

The soil texture is silty clay loam, alkaline in reaction (pH 8.2 and 8.1), soil EC (0.19 and 0.25 dSm^{-1}), low in organic matter (0.88 and 0.72%), and total N (0.05 and 0.08%) in 2011 and 2013 respectively.

Experimentation

A three factor factorial experiment was conducted at New Developmental Farm, University of Agriculture Peshawar Pakistan during year 2011and 2013. Maize hybrid Baber was planted on the experimental plot established on 20th June 2011. The experiment was repeated on 22nd June 2012 and on 25th June 2013 on the same plots according to randomized complete block (RCB) design having three replications. Experiment in 2012 failed due to sever infestation by weeds. Four N levels (120, 160, 200 and 240 kg N ha^{-1}) and four S levels (20, 25, 30 and 35 kg S ha^{-1}) applied in three ratios viz R1(10:50:40), R2(20:50:30) and R3 (30:50:20) i.e. 50% of N and S were applied at V8 stage, while 10, 20 and 30 % were applied at sowing and 40, 30 and 20% were applied at tasseling in Ratio 1, 2 and 3. Each replication had also a control treatment, where no N or S was applied. A plot size of 3m x 5m with 70 cm apart rows and plant to plant distance of 25cm was maintained. A basal dose of 120 kg phosphorous ha^{-1} in the form of diammonium phosphate (DAP) and 125 kg K_2O ha^{-1} in the form of murate of potash (MOP) was used. N and S were applied in three splits: 1^{st} at time of sowing, 2nd at V8 and 3^{rd} at VT stage (Khalil *et al.,* 2008). Each year, wheat was grown after harvest of maize. Metrological data was recorded at weather station located at Regional metrological center Peshawar (Fig. 1 and 2). Data on days to emergence and silking were recorded when more than 50% plants emerged in case of emergence and 50% plants completed silking in each treatment. Days were counted from date of sowing till the completion of more than 50% emergence and silking respectively. Stover yield was calculated by the following formula.

Stover yield = Biological weight - ear weight

The EC was measured in a saturated extract with the help of EC meter (Garcia *et al.*, 1999).

Statistical analysis

The data was statistically analyzed using analysis of variance appropriate for 3-factorial treatment arrangement in randomized complete block design using statistical package statistix v.8.1. Analysis was performed to detect the variation between the years. Means were separated using least significant difference (LSD) test at 0.05 level of probability (Steel *et al.*, 1997).

Results and discussion

Days to 50% emergence

Year (Y), nitrogen (N), sulfur (S), ratios (R), control vs. fertilized and their interactions showed non-significant effect on days to 50% emergence (Table 1).

Table 1. Mean squares of various parameters of maize hybrid 'Babar' as affected by nitrogen, sulfur and their ratios over years.

Sources of Variance	DF	Days to emergence	Days to Tasseling	Stover yield	Soil EC
Year (y)	1	0.7207	0.0003	0.0000	0.4130
Rep (R)	4	0.2897	0.5167	0.4784	0.0627
Treatment	48	0.9872	0.0000	0.0000	0.0000
Nitrogen	(3)	0.8303	0.0000	0.0000	0.0000
Sulfur	(3)	0.9760	0.0506	0.0078	0.0000
Ratio	(2)	0.6829	0.0349	0.1019	0.7557
N × S	(9)	0.9135	0.5829	0.0390	0.4109
N × R	(6)	0.4919	0.2270	0.6298	0.6114
S × R	(6)	0.9695	0.7057	0.3501	0.4268
N ×S x R	(18)	0.7086	0.2814	0.1800	0.6578
Control vs fertilized	(1)	0.3642	0.0000	0.3267	0.0044
Y × T	48	0.9840	0.9989	0.0001	0.1833
Y × N	(3)	0.9612	0.8297	0.0006	0.0169
Y × S	(3)	0.5628	0.9285	0.0460	0.3659
Y × R	(2)	0.2602	0.9941	0.9325	0.1277
Y × N × S	(9)	0.9860	0.9395	0.0061	0.0308
Y × N × R	(6)	0.3908	0.8467	0.0349	0.5356
Y × S × R	(6)	0.4454	0.6819	0.0187	0.8947
Y × N × S × R	(18)	0.9656	0.9804	0.5693	0.7177
Y x control vs fertilized	(1)	0.6498	0.0867	0.0010	0.9870
Error	192				
Total	293	10.35	2.4	4.1	13

Table 2. Days to 50% silking of maize hybrid 'Babar' as affected by nitrogen, sulfur and their ratios over year.

N (kg ha^{-1})	Year		Mean
	2011	2013	
120	59	61	60d
160	62	63	62c
200	63	65	64b
240	65	67	66a
LSD			0.46
S (kg ha^{-1})			
20	63	64	64a
25	62	64	63b
30	62	64	63b
35	62	64	63b
LSD			0.46
Ratios			
R1 (10:50:40)*	62	64	63b
R2 (20:50:30)	62	64	63b
R3 (30:50:20)	63	64	64a
LSD			0.40
Control vs. fertilized			
Control	57	57	57b
Rest	62	64	63a
Mean	62b	63a	

Means of each category followed by same letters are not significantly different at ($P \leq 0.05$) using LSD test.

* 10, 20 and 30 % of N and S were applied at sowing 50% of N and S were applied at V8 while and 40, 30 and 20% were applied at tasseling in Ratio 1, 2 and 3.

However, the higher amount of N and S application took more days to 50% emergence compared to low rates of the N and S application (data not shown).

Days to 50% silking

Y, N, R, control vs fertilized significantly affected days to 50% silking (Table 1). Mean values for Y showed that silking was delayed (63 days) in the 2013 compared with 2011 in which silking occurred in 62 days (Table 2). Mean values for N levels revealed that days to 50% silking increased with each increment of N up to 240 kg N ha^{-1}. More days to 50% silking (64 days) were taken by R3 (30:50:20) compared to R1 (10:50:40) and R2 (20:50:30). Control plots required fewer days to 50% silking (57) compared with fertilized plots (63).

Table 3. Stover yield (kg ha^{-1}) of maize 'Babar' as affected by nitrogen, sulfur and their ratios over year.

N (kg ha^{-1})	Year		Mean
	2011	2013	
120	6355	6156	6256c
160	6570	6794	6682b
200	6752	74023	7077a
240	7010	7275	7143a
LSD			190
S (kg ha^{-1})			
20	6766	6833	6800ab
25	6433	70111	6722b
30	6593	6712	6652b
35	6896	7071	6983a
LSD			190
Ratios			
R1 (10:50:40)*	6614	6811	6712
R2 (20:50:30)	6637	6888	6763
R3 (30:50:20)	6764	7021	6893
LSD			
Control vs. fertilized			
Control	6237	6326	6282b
Rest	6672	6907	6790a
Mean	6670b	6932a	

Means of each category followed by same letters are not significantly different at ($P \leq 0.05$) using LSD tests.

* 10, 20 and 30 % of N and S were applied at sowing 50% of N and S were applied at V8 while and 40, 30 and 20% were applied at tasseling in Ratio 1, 2 and 3.

The significant difference in days to silking over the years may be due to the loss of nutrient by leaching through heavy rainfall in 2011 (278 mm) compared to 131mm rainfall occurred in 2013 (Fig. 1 and 2). The increase in days to tasseling may be due to the fact that nitrogen influences vegetative growth of crop and crop canopy that delayed tasseling. Our results agree with the findings of Amanullah *et al.*, (2009) and Toor *et al.*, (1990) who reported that days to silking increased in linear fashion with the increase in N. Maximum days to silking at R3 may be due to the fact that maize received 30% of its required fertilizer dose at sowing and 50% at V8 stage which was much higher compared with R1 and R2. This higher dose promoted vegetative growth and delayed days to silking.

Table 4. Soil electrical conductivity (d S m^{-1}) as affected by nitrogen, sulfur and their ratios over year.

N (kg ha^{-1})	Year		Mean
	2011	2013	
120	0.225	0.236	0.231c
160	0.242	0.257	0.250b
200	0.253	0.268	0.260ab
240	0.272	0.256	0.264a
LSD			0.014
S (kg ha^{-1})			
20	0.234	0.236	0.235c
25	0.253	0.252	0.252b
30	0.249	0.257	0.253b
35	0.257	0.272	0.264a
LSD			0.014
Ratios			
R1 (10:50:40)*	0.248	0.252	0.250
R2 (20:50:30)	0.246	0.261	0.254
R3 (30:50:20)	0.253	0.249	0.251
LSD			
Control vs. fertilized			
Control	0.210	0.216	0.213b
Rest	0.248	0.254	0.251a
Mean	0.229	0.235	

Means of each category followed by same letters are not significantly different at ($P \leq 0.05$) using LSD test.

* 10, 20 and 30 % of N and S were applied at sowing 50% of N and S were applied at V8 while and 40, 30 and 20% were applied at tasseling in Ratio 1, 2 and 3.

Stover yield (kg ha^{-1})

Y, N, S, R, control vs fertilized treatment and interaction between N and S significantly affected stover yield (Table 1). Higher stover yield (6932 kg ha^{-1}) was observed in 2013 compared with 2011 (6670 kg ha^{-1}) (Table 3). Stover yield increased with increment of N and higher stover yield (7142 kg ha^{-1}) was obtained with 240 kg N ha^{-1}. Higher S levels (35 kg S ha^{-1}) produced more stover yield (6883 kg ha^{-1}) compared with lower S levels (20 kg S ha^{-1}). Control plots produced minimum stover yield (6282 kg ha^{-1}) compared with fertilized plots (6790 kg ha^{-1}). N x S interaction showed that stover yield increased with increase in N from 120 to 200 with all S rates. Further increase in N only increased SY with 20 and 35 kg S ha^{-1} (Fig. 3). Stover yield was significantly higher in 2013 as compared to 2011. Lower yield in 2011 may be due to the excessive loss of nutrient because of leaching through heavy rainfall in 2011 growing season (278mm) compared to 131mm rainfall occurred in 2013 (Fig. 1 and 2). Significant increase in yield due to N may be due to the reason that nitrogen enhances vegetative growth which results more dry matter production and more biological yield. These findings matched the results of previous researchers like El-Sheikh *et al.* (1998), Derby *et al.* (2005), Monasterio *et al.* (1997), Azeem *et al.* (2014), and Hayat *et al.* (2015), who obtained more stover yield with increased increasing N application. Similarly, the application of N increased the vegetative growth (Zeidan *et al.,* 2006), and hence enhanced the biological yield. Stover yield of maize was significantly enhanced with the application of S compared with control (Khan *et al*., 2006).

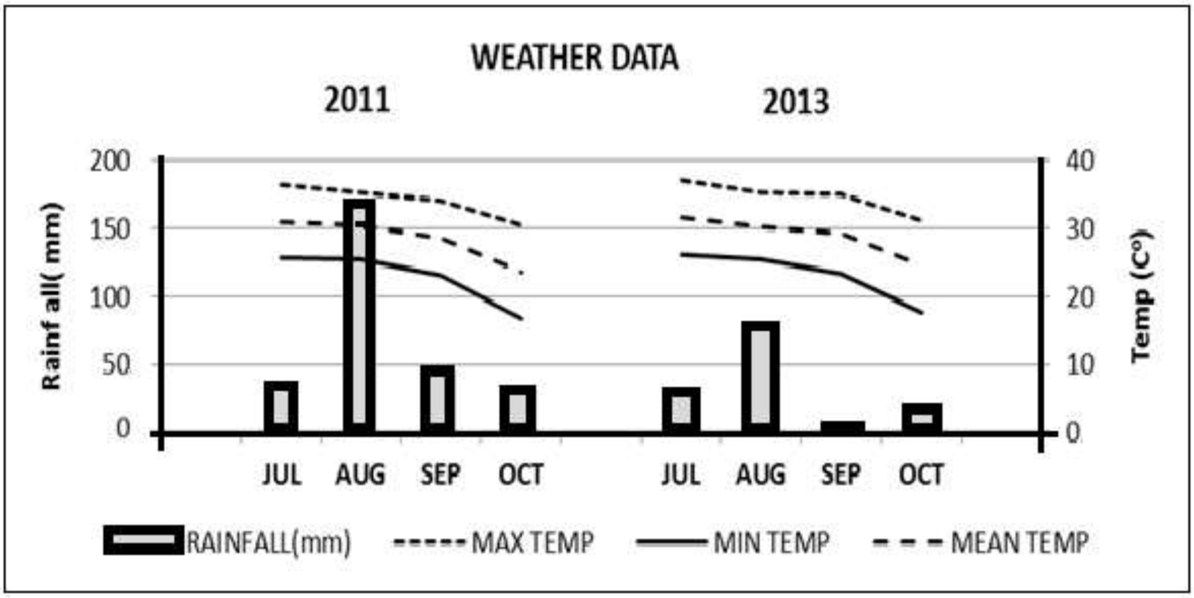

Fig. 1. Monthly rainfall recorded during 2011 and 2013 during maize growing season.

Combined S × N application significantly enhanced stover yield. It may be due to the fact that combined N × S applications have synergistic effect causing increase in uptake of both nutrients resulting in vigorous growth and more biomass production. Our results are in line with Singh *et al.* (1991) and Dev *et al.* (1988) who reported higher biomass yield from combined application of N x S. Lower stover yield in case of control plots may be due to deficiency of these nutrient element in soil compared with fertilized plots.

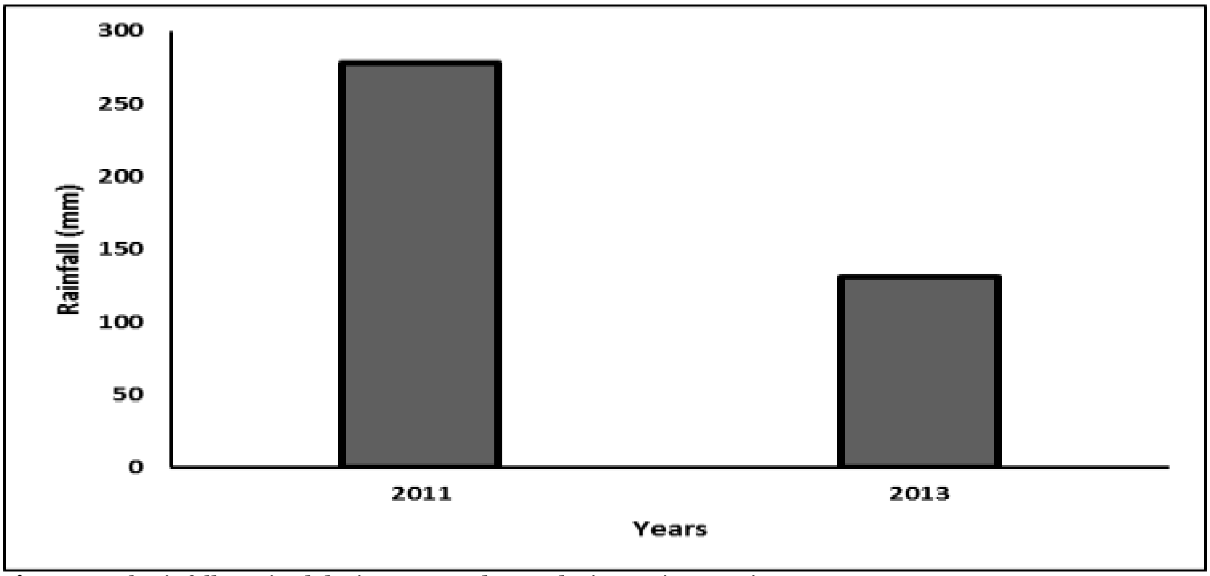

Fig. 2. Total rainfall received during 2011 and 2013 during maize growing season.

Soil electrical conductivity (EC)

N, S and control vs fertilized significantly affected the soil EC (Table 1). Mean values for N revealed that soil EC increased with each increment of N level and maximum EC (0.264) was observed with 240 kg N ha-1 (Table 4). Mean values of S showed that lower soil EC (0.235) was observed with low levels of S (20 kg S ha^{-1}) whereas high soil EC (0.264) was noted at 35 kg S ha^{-1}. Control plots resulted in lower soil EC (0.213) compared with fertilized plots. Higher soil EC values at higher application of N and S may due to more accumulation of N and S compared with lower levels and control. Our results are in line with Selvakumari *et al.* (2000) who reported higher soil EC with the application of inorganic and organic fertilizer and was further confirmed by Sarwar *et al.* (2008).

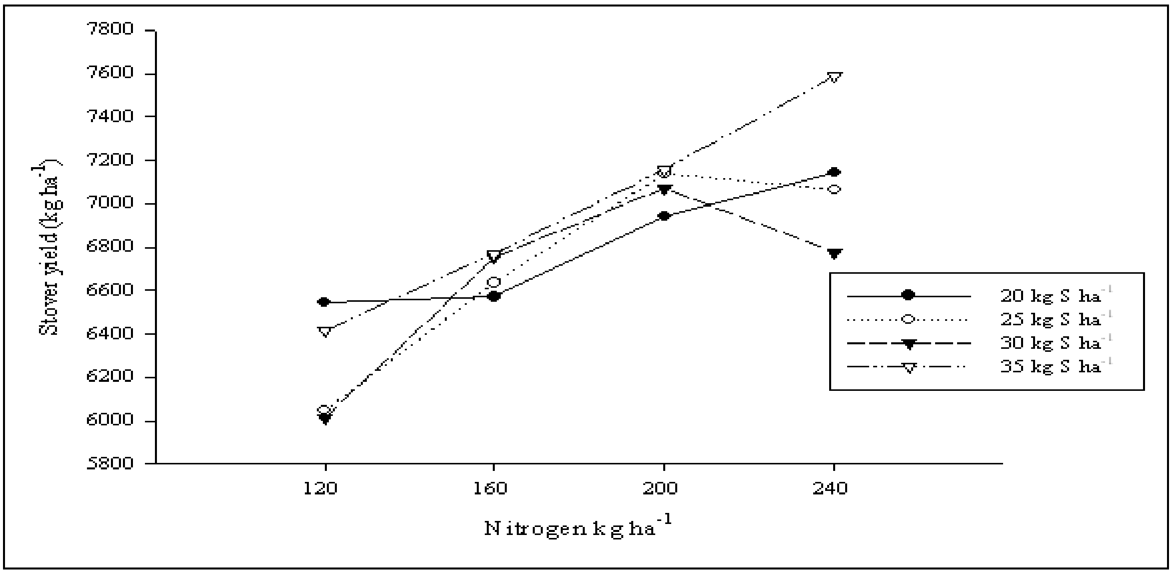

Fig. 3. Stover yield (kg ha-1) of maize hybrid 'Babar' as affected by nitrogen and sulfur interaction.

Conclusion

Application of higher N (240 kg ha-1) had delayed days to silking (66 days) via lengthening of vegetative growth, and increased stover yield (7143 kg ha-). However, the application of 20 kg S ha-1 had enhanced silking (63 days), but the higher stover yield (6983 kg ha-1) was observed with 35 kg S ha-1.

The application of R3 (i.e. 30% at sowing, 50% at V8, and 20% at tasseling stages) had delayed the silking (64 days), and increased the stover yield (6893 kg ha-1) as compared to other ratio applied at these stages. Therefore, the aapplication of 240 kg N ha-1 and 35 kg S ha-1 in the ratios of 30% at sowing, 50% at V8, and 20% at tasseling stages is recommended for obtaining higher SY of maize hybrid Babar.

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