Research Article

Effect of Nitrogen and Sulfur on Maize Hybrids Yield and Post-Harvest Soil Nitrogen and Sulfur

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Abstract | Balanced nutrition is imperative for efficient nutrient management and has considerable role in enhancing crop yield. To study the effect of nitrogen (N) and sulfur (S) on maize hybrids, field experiments were laid out at the Agronomy Research Farm, the University of Agriculture Peshawar, Pakistan during 2013 and 2014, respectively. Nitrogen (0, 250, 300, 350 kg ha^{-1}) and Sulfur (0, 20, 40, 60 kg ha^{-1}) in main plots, whereas maize hybrids (R-3305, R-2210, R-2207) in subplots, were replicated thrice in randomized complete block design with split plot arrangement. Maximum biological yield, grain yield and harvest index were recorded with 350 kg N ha^{-1}. Among studied maize hybrids, R-2210 achieved more biological yield, grain yield and harvest index than R-3305 and R-2207. Maximum net income and benefit cost ratio (BCR) were recorded in plots with 350 kg N and 40 kg S ha^{-1} for R-2210. Nitrogen and sulfur content in soil and tissue were substantially increased with application of both the nutrients. However, sulfur content in plant tissue did not vary with increasing N from 250 to 350 kg ha^{-1}, but was considerably improved with respect to control. It is concluded that R-2210 produced maximum yield, BCR value and N content in tissue with 350 kg N ha^{-1}, however S content in soil and in tissue was more with 40 kg S ha^{-1}. Hence, it is recommended that 350 kg N ha^{-1}, and R-2210 should be used for optimum grain yield and economic benefits.

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Introduction

Maize is grown successfully throughout Pakistan, particularly in Punjab and in Khyber Pakhtunkhwa. Maize is an exhaustive crop and requires both macro and micronutrients in balanced quantity for optimum growth and development. Application of all essential nutrients, particularly nitrogen (N) and sulfur (S) in optimum quantity, not only enhance grain yield of maize, but also grain quality (Sule et al., 2014; Mahmood et al., 2000). Application of balanced nutrition is thus a vigorous feature of nutrient management and have central role in enhancing crop growth and production. The availability of nutrients such as N, P, K, S and Mg in appropriate amount is crucial for growth and yield (Mahmood 1994; Randhawa and Arora, 2000). Nitrogen is one of the most yield limiting nutrients among major nutrients needed for higher yield worldwide. Nitrogen being constituent of the building blocks of protein, chlorophyll and almost all plant structures (Verma et al., 2012) involved in many physiological and biochemical processes and hence improving maize growth. Nitrogen not only stimulates root growth and crop development but also has a synergistic effect on other nutrients as well (Smil, 2001). Due to this reason, it is the largest applied nutrient to most of annual crops and have substantial influence on growth and yield of maize crop (Huber and Thompson, 2007). Higher amount of mineral N under varied agro-ecological conditions had enhanced maize yield, dry matter production, ears m^{-2}, plant height and thousand grains weight (Merkebu and Belete, 2013; Geremew, 2009; Kidist, 2013). Though, the application depends on environmental conditions i.e. precipitation, cultivars and potential yield of the crop. Increasing N levels had significantly enhanced grains ear^{-1}, thousand grain weight and ultimately maize grain yield (Hokmalipour et al., 2010). Due to higher yield potential of maize hybrids, many researchers have reported differences in maize yield with different levels of nitrogen at various climatic and soil factors (Arif et al., 2010).

Sulfur is also an essential nutrient for plant growth and development as it is a part of major metabolic compounds such as amino acids (methionine and cysteine), glutathione, proteins, and sulpho-lipids. The demand and plant requirement for sulfur and metabolism in maize plants are closely related to N supply (Reuveny et al., 1980) and S status (Duke and Reisenauer, 1986) of the plant. Sulfur deficiency in the soil adversely affect uptake of nitrate and natural process of nitrate reductase (Prosser et al., 2001), and result in steady-state nitrate accumulation in maize (Gilbert et al., 1997). Rasheed et al. (2003) reported that N applied to maize crop along with the S, resulted significantly in higher yield and yield components than NPK alone and also than NPK with Mg application. Combined application of sulfur and nitrogen to maize, not only increase nitrogen use efficiency but also sulfur use efficiency (Fismes et al., 2000). It is therefore, essential to know the best level of both N and S for getting a higher maize yield, so that maximum benefits could be achieved.

The present study was therefore designed to find out the effect of N and S levels on maize hybrids biological yield, grain yield, harvest index, benefit cost ratio and their concentration in the soil and in maize tissue and to suggest the best level of both nutrients (N and S) and their best interaction to the farmers for optimum maize grain yield.

Materials and Methods

Experimental Site

Field study of two years was carried out at the Agronomy Research Farm (34° 01′ N, 71° 40′ E), the University of Agriculture, Peshawar, Khyber Pakhtunkhwa, Pakistan. The university research farm has a warm to hot, semi-arid, subtropical, continental climate with mean annual rainfall of approximately 360 mm (Arif et al., 2015). Previous crop grown on experimental site was pigeon pea.

Table 1: *Soil physical and chemical properties at selected experimental site*

Soil Property	Soil layers (cm)	
	0-15	15-30
Sand (%)	43.6	45.2
Silt (%)	45.5	33.4
Clay (%)	13.0	9.0
pH	7.36	7.63
Organic matter (%)	1.06	1.32
NO_3-N (mg kg^{-1})	7.00	5.00
Total nitrogen (%)	0.148	0.096
P (mg kg^{-1})	1.98	1.19
K (mg kg^{-1})	110	112
Sulfur (mg kg^{-1})	3.00	3.00

Soil Analysis

Soil samples were collected from the experimental site (0-15 and 15-30 cm depth) and analyzed for physico-chemial characteristics of soil before sowing (Table 1). However, post-harvest soil and plant analysis was done for nitrogen and sulfur only. The experimental soil was well drained, silty clay loam and calcareous in nature (pH 8.23±0.09). The soil was low in mineral nitrogen (5 mg kg^{-1} of soil), phosphorous (1.19 mg kg^{-1} of soil), potassium (112 mg kg^{-1} of soil), sulfur (3 mg kg^{-1} of soil) and organic matter (less than 1%). Organic matter was determined through a wet oxidation method based upon the Walkley and Black method (Nelson and Sommers, 1982). Phosphorus was measured by spectrophotometer and potash by flame photometer. Total N in the soil was determined by Kjeldhal digestion, distillation and titration method (Bremner and Mulvaney, 1982). The extractable phosphorous and potassium in the soil samples from the selected site was determined and analyzed by using AB-DTPA extractable method and procedure. For determination of S_{min} in soil and in plant, the most commonly used method is the extraction of SO_4-S with 0.15% $CaCl_2$. $2H_2O$ and measurement of SO_4-S concentration in the extracts by autoturbidimetric procedure using barium chloride (Verma, 1977). Mean monthly rainfall and temperature for both years are presented in Figure 1 and 2, respectively.

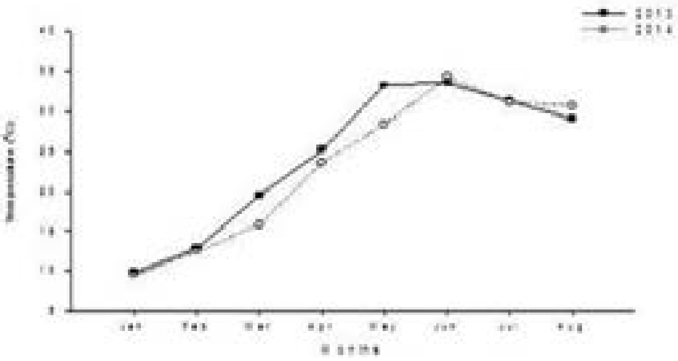

Figure 1: *Mean monthly temperature for the year 2013 and 2014*

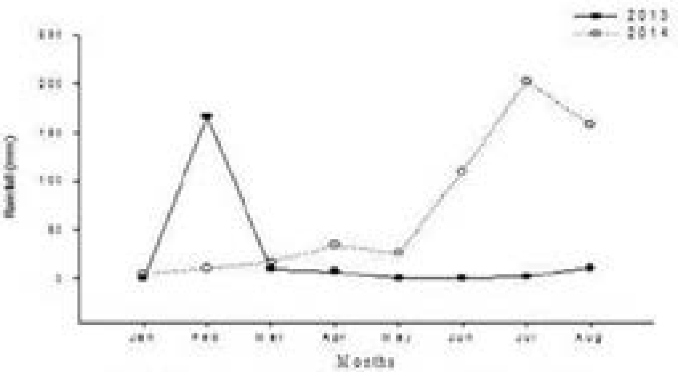

Figure 2: *Mean monthly rainfall for the year 2013 and 2014*

To study and analyze the ameliorative effect of various macro nutrient applications on maize hybrids yield and post-harvest soil N and S status, field trials were carried out over two growing seasons during 2013 and 2014, respectively. The design was a randomized complete block with a split plot arrangement in three replications. Nitrogen levels (0, 250, 300, 350 kg ha^{-1}) and sulfur levels i.e., 0, 20, 40, and 60 kg ha^{-1}, were applied in main plots while maize hybrids i.e. R-3305, R-2210 and R-2207 were allotted to subplots. Sowing during both years of study was done on 5th March and all basal doses of fertilizers were applied on 4th March 2013 and 2014, respectively. Nitrogen was applied in split doses i.e. 1/3rd in seedling stage, 1/3rd at knee stage and the remaining amount was applied at tasseling stage, whereas sulfur was applied all in sowing time. For nitrogen, urea was applied as source, while for sulfur; ammonium sulfate was used. Irrigation was done weekly for all experimental units, however during pollination stage, field was irrigated twice per week. For weeds control, Premixtra was used @ 2 liters ha^{-1}as pre-emergent herbicide. For stem borer and shoot fly control, Carbofuron @ 8 kg ha^{-1} was used. Carbofuron was applied when the crop was at sixth leaf and knee height stage. For white fly and aphids control Imida cloprid @ 1 kg ha^{-1} was used. Harvesting of the crop was done in 2nd week of August during both growing seasons. The parameters studied were, biological yield, grain yield, harvest index, mineral nitrogen in the soil (N_{min}), total nitrogen in the maize plant tissue (N_{total}), mineral sulfur in soil (S_{min}), total sulfur in maize plant tissue (S_{total}) and economic analysis for all maize hybrids. Post-harvest soil samples were taken from each subplot and the required parameters were calculated using procedures as mentioned above. Data of biological yield was recorded by harvesting dried plant of the three central rows in each subplot and were weighed and the data were obtained by using the following formula:

$$\text{Biological yield (kg ha}^{-1}) = \frac{\text{Weight of dried plants of three central rows}}{\text{Row length x R} - \text{R distance x no. of rows}} \times 10000$$

Grain yield was recorded of shelling of three central rows of corn plants and grains were weighed and the data were obtained by using the following formula:

$$\text{Grain yield (kg ha}^{-1}) = \frac{\textit{Grain weight of three central rows}}{\text{Row length x R} - \text{R distance x no. of rows}} \times 10000$$

Harvest index is the ratio of grain and biological yield and was obtained for each plot by using the following formula. It is a unit less and expressed in percentage.

$$\text{Harvest Index (\%)} \quad \frac{\text{Grain yield}}{\text{Biological yield}} \times 100$$

For economic analysis, the benefit cost ratio was calculated by dividing the gross income by the total expenditure (Rasheed et al., 2003) by using the formula given below:

$$\text{Benefit cost ratio} = \frac{\text{Gross income}}{\text{Total Expenditure}} \times (\text{PKR. ha}^{-1})$$

The data collected was tested according to the ANOVA technique for Randomized Complete Block (RCB) design with split plot arrangement using the statistics 8.1 software. The treatment means were compared at $P < 0.05$ level of probability using LSD test (Jan et al., 2009).

Results and Discussion

Biological Yield (kg ha^{-1})

Nitrogen levels, maize hybrids and years had a

Table 2: *Effect of nitrogen and sulfur on biological yield (kg ha^{-1}), grain yield (kg ha^{-1}) and harvest index (%) of maize hybrids*

	Biological yield		Grain yield		Harvest index	
S (kg ha^{-1})	2013	2014	2013	2014	2013	2014
0	19783	20070	5866	5882	28.19	28.85
20	19712	19905	5907	5873	28.78	28.97
40	19519	19953	5846	5888	28.88	29.06
60	20038	20009	5973	5948	28.67	29.57
$LSD_{(0.05)}$	ns	ns	ns	ns	ns	ns
N (kg ha^{-1})						
0	13582 d	13073 c	3011 d	2928 d	21.44 d	22.45 d
250	20343 c	22088 b	5560 c	5574 c	27.43 c	25.31 c
300	22156 b	22761 a	7008 b	7000 b	31.09 b	30.78 b
350	22972 a	22015 b	8013 a	8089 a	34.54 a	37.91 a
$LSD_{(0.05)}$	866.69	321.57	132	79	0.88	0.65
Hybrids						
R-3305	19944 a	20031 b	5607 c	5637 c	27.11 c	28.04 b
R-2210	19422 b	20186 a	6050 a	6076 a	30.07 a	29.85 a
R-2207	19923 a	19736 c	6037 b	5980 b	28.70 b	29.44 a
$LSD_{(0.05)}$	413.45	275.31	81	56	0.63	0.47
Years	19763 b	19984 a	5706 b	5849 a	28.63 b	29.11 a
Interaction						
S x N	ns	**	ns	ns	**	ns
S x H	ns	ns	ns	ns	ns	ns
N x H	**	**	**	**	**	**
S x N x H	ns	ns	*	ns	ns	ns

Means followed by different letters are significantly different from each other at 5% level of probability; *****: *Significant at 5% level of probability;* ******: *Significant at 1% level of probability;* **ns:** *Non-significant*

significant effect on biological yield (Table 2), however, sulfur levels did not considerably affect biological yield. Biological yield increased up to 22972 kg ha^{-1} with 350 kg N ha^{-1} during 2013, which was statistically similar to biological yield produced with 300 kg N ha^{-1} in 2014 (22761 kg ha^{-1}). The lowest biological yield during 2013 and 2014 was observed in control plots. The improvement in biological yield under increasing N could also be due to the accelerated crop growth rate, LAI and accumulation of phtoassimilates (Hammad et al., 2011; Kandil, 2013). It has been found that a substantial increment in N level enhanced biological yield (Rahmati, 2012). The same results were also reported by Ayman and Samier (2015) who found that a higher biological yield was produced with 330 kg N ha^{-1}. Likewise, application of N at rate of 150 kg ha^{-1} had increased biological yield (Akmal et al., 2010). Hammad et al. (2011) also exhibited that nitrogen application at rate 300 kg ha^{-1} had increased biological yield of maize. Maize hybrid R-2207 produced higher biological yield (19923 kg ha^{-1}) as compared to R-2210 and R-3305 during 2013, however R-2210 produced higher biological yield (20186 kg ha^{-1}) during 2014 as compared to R-3305 (20031 kg ha^{-1}) and R-2207 (19736 kg ha^{-1}), respectively. Though S had non-significant effect on biological yield yet Rasheed et al. (2003) reported that sulfur considerably increased dry biomass. Interaction between N and hybrid showed that biological yield of R-3305 and R-2207 increased with application of 350 kg N ha^{-1} as compared with R-2210 (Figure 3) and this could be due to differential potential among the hybrids for higher nitrogen uptake. The findings of Wasaya et al. (2012) were also in accordance with the present study as they reported that maize hybrids has different genetic potential and showed a substantial response to biological yield with increasing N levels. The higher biological yield (19984 kg ha^{-1}) during 2nd year of the study as compared to the first year (19763 kg ha^{-1}) might be due high rainfall and low temperature during 2014 as compared to 2014 (Figure 1 and 2). The other reason could be the residual effect of 1st year as in 2nd year the crop was grown on same plots and received both N and S. Akongwubel et al. (2012) also reported differences in dry matter yield among years.

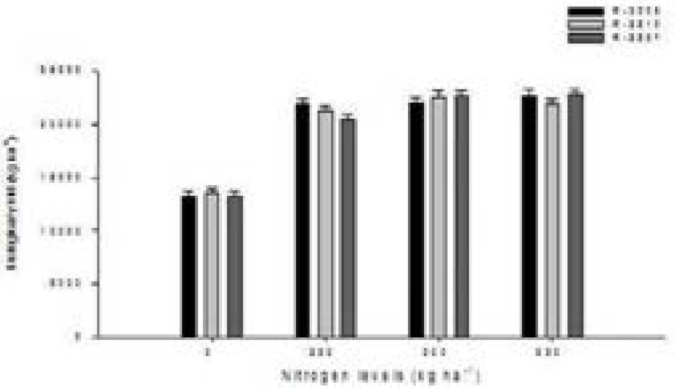

Figure 3: *Biological yield of maize hybrids grown with four levels of nitrogen and sulfur*

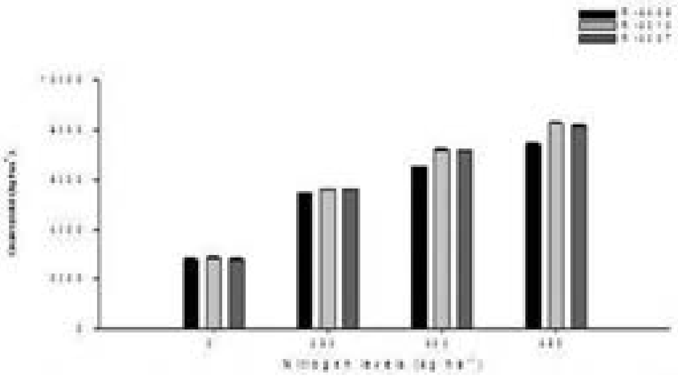

Figure 4: *Grain yield of maize hybrids grown with four levels of nitrogen and sulfur*

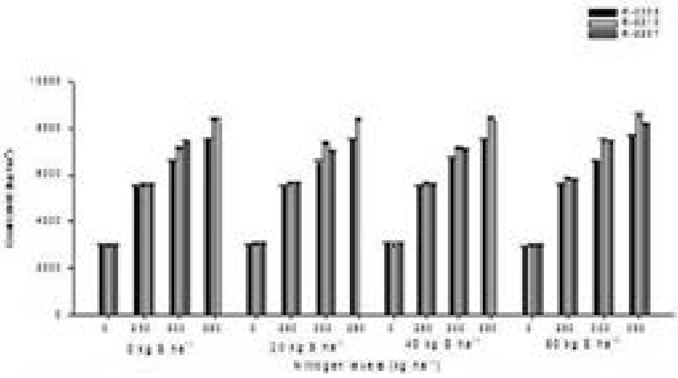

Figure 5: *Interaction between nitrogen, hybrid and sulfur for grain yield of different corn hybrids*

Grain Yield (kg ha^{-1})

Grain yield of maize hybrids was considerably influenced by N levels, hybrids and years, whereas sulfur levels had not substantial influence on grain yield. None of the interaction was found significant except N x H and S x N x H (Table 2). Higher grain yield of 8013 and 8089 kg ha^{-1} was produced with N level of 350 kg ha^{-1} during 2013 and 2014, respectively when compared with control. The higher grain yield with maximum level of N might enhance photosynthetic rate which leads to a higher partitioning of assimilates to the economic portion. Huseyin and Konukan (2010) also described that grain yield increased for N application up to 240 kg N ha^{-1}. Likewise, Al-Kaisi and Yin (2003) concluded that N applied at rate of 250 kg ha^{-1} was found beneficial for higher yield of maize. It has been observed that maize grain yield significantly increased with increasing levels of nitrogen (Inamullah et al., 2011; Mahdi and David, 2005). Application of nitrogen enhanced both grain yield and total dry matter (Kiros, 2007). Maize hybrid R-2210 produced the highest grain yield of 6050 and 6076 kg ha^{-1}, respectively, during both growing seasons. The difference in grain yield of the hybrids might the differential genetic potential of the hybrids (Inamullah et al., 2011). Grain yield was lower (5706 kg ha^{-1}) during 2013 than during the year 2014 (5849 kg ha^{-1}). This might be due to high rainfall and favorable temperature during the 2nd year of the study. Interaction of N x H indicated that maize hybrids responded linearly for grain yield with N levels, however R-2210 was more responsive as compared to R-3305 and R-2207 (Figure 3). Interaction between N x H x S revealed that hybrid R-2210 produced higher grain yield when N and S applied at rate of 350 kg ha^{-1} and 40 kg ha^{-1} , respectively as compared to hybrids R-3305 and R-2207. Akmal et al. (2010) also found differential response of maize hybrids to higher rates of N and S levels.

Harvest Index (%)

Harvest index was significantly affected by N levels, maize hybrids and years while the effect of S was found non-significant (Table 2). Mean values for N levels showed that harvest index increased more during 2014 than 2013, up to 37.91% in experimental units applied with 350 kg N ha^{-1}, followed by 300 kg N ha^{-1} (30.78%) and 250 kg N ha^{-1} (25.31%), respectively as compared to control plots (22.45%). However, the trend of harvest index was linear with increase in N levels during both years of study. The probable reason could be that nitrogen enhanced grain and biological yield of maize hybrids and hence, more value of harvest index was recorded. Inamullah et al. (2011)

agreed with these findings and reported that nitrogen levels enhanced harvest index linearly because of increase in ratio of grain and biomass yield. Sulfur levels did not affect biological and grain yield significantly, hence, harvest index effect was non-significant. However, Szulc et al. (2012) did not agree with these results and reported that sulfur significantly affected the grain yield and ultimately, harvest index. R-2210 produced maximum values for harvest index (30.07 and 29.85%) during 2013 and in 2014, respectively, followed by R-2207 (28.70 and 29.44%) and R-3305 (27.11 and 28.04%). Azam et al. (2007) reported similar results that maize hybrids affected the harvest index significantly and different hybrids had a varied response to nitrogen levels. Interaction of S x N was significant at 5% and N x H was significant at the 1% level of probability on harvest index as shown in Figure 6 and 7, respectively. Inamullah et al. (2011) also reported similar results and found that each hybrid has a significant interaction with nitrogen for harvest index, which might be due to its different genetic potential. Years had a significant effect on harvest index and more harvest index was observed (29.11%) during the second year as compared to the first year of the study (28.63%).

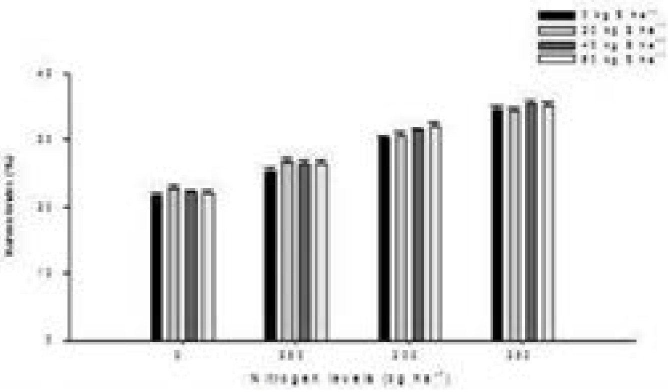

Figure 6: *Harvest index of maize hybrids grown with four levels of nitrogrn and sulfur*

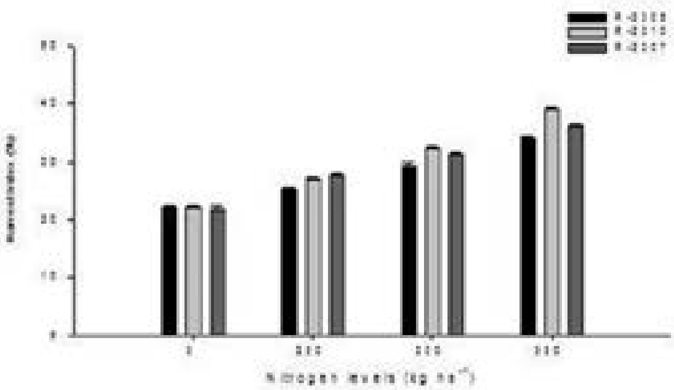

Figure 7: *Harvest index of maize hybrids grown with four levels of nitrogrn and sulfur*

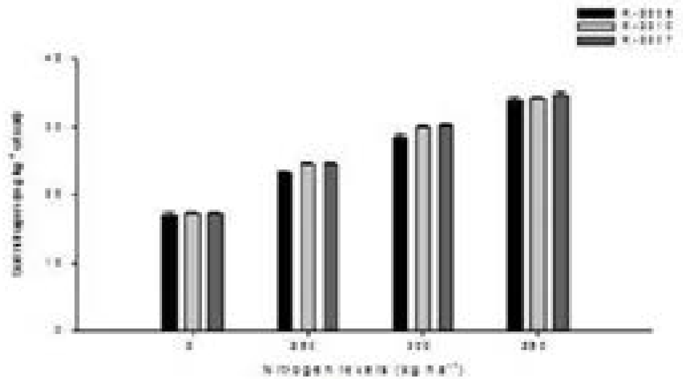

Figure 8: *Post-harvest soil nitrogen status of maize hybrids grown with four levels of nitrogen and sulfur*

Post-harvest Soil Analysis

Statistical analysis of the data showed that nitrogen levels had significant effect on mineral nitrogen and sulfur in the soil; however sulfur levels had significantly affected sulfur in soil during 2013 and 2014, respectively, and had a non-significant effect on mineral nitrogen in the soil (Table 3). The highest value of mineral nitrogen (N_{min}) was recorded in plots applied with 350 kg N ha^{-1}in 2013 as compared to 2014. Among studied hybrids, experimental units of R-2210 and R-2207 had been reported as maximum value for N_{min}. Interaction between N x H indicated that both R-2210 and R-2207 responded significantly to all N levels when compared with R-3305, however the trend lines of R-2210 and R-2207 were non-significant with each other. Nevertheless, after 300 kg N ha^{-1}, more value for N_{min} was reported in plots of R-2210 as compared to R-2207 (Figure 8). It has been noted that when the land is deficient in S, nitrogen uptake is minimized and rather subdued, which demonstrated the synergistic relationship of these two nutrients (Fazli et al., 2008). Balancing of N with S level has always been significant for higher yield. Moreover, N and S interaction significantly influenced soil N and S content (Ray and Mughogho, 2000) and their concentration in plant leaf increased with a provision of these two nutrients in only nutrient deficient patches. The soil application of nitrogen depends in a high degree on the balancing of nitrogen with the dosage of sulfur. Experimental plots treated with the 60 kg S ha^{-1} had maximum values of S in the soil when compared with un-amended plots in 2013 as compared to 2014. Moreover, mean values for N levels showed that maximum S_{min} has been reported in un-amended plots which indicated that N and S have a good synergistic relationship. Among hybrids, R-3305 and R-2210 had non-significant relation with each other, but significant with R-2207.

Table 3: *Effect of nitrogen and sulfur on post-harvest soil (mg kg^{-1} of soil) and tissue of N and S (%) of maize hybrids*

	Mineral N in soil		Mineral S in soil		N in tissue		S in tissue	
S (kg ha^{-1})	**2013**	**2014**	**2013**	**2014**	**2013**	**2014**	**2013**	**2014**
0	28.93	23.61	4.55 d	4.51 d	1.14	1.15	0.02 d	0.02 c
20	28.57	23.53	7.86 c	7.63 c	1.19	1.17	0.12 c	0.14 bc
40	29.00	23.44	13.27 b	12.96 b	1.13	1.14	0.24 a	0.24 a
60	28.65	23.64	17.42 a	16.86 a	1.16	1.20	0.24 a	0.24 a
$LSD_{(0.05)}$	ns	ns	0.76	0.75	ns	ns	0.0042	0.0074
N (kg ha^{-1})								
0	17.56 d	16.64 d	10.91	10.51 a	0.71 d	0.70 d	0.15 b	0.15 b
250	25.56 c	22.39 c	11.05	10.93 a	1.02 c	1.01 c	0.16 a	0.16 a
300	33.57 b	25.39 b	11.01	11.01 a	1.22 b	1.28 b	0.16 a	0.16 a
350	38.47 a	29.81 a	10.12	9.51 b	1.68 a	1.67 a	0.15 a	0.16 a
$LSD_{(0.05)}$	1.79	0.50	ns	0.53	0.054	0.045	0.0042	0.0074
Hybrids								
R-3305	28.05 c	23.13 b	10.78 b	10.25 b	1.15 b	1.15 c	0.15	0.16
R-2210	29.20 a	23.50 b	10.50 b	10.19 b	1.20 a	1.20 a	0.15	0.16
R-2207	29.11 a	24.04 a	11.01 a	11.03 a	1.15 b	1.16 b	0.16	0.16
$LSD_{(0.05)}$	0.65	0.32	0.60	0.84	0.017	0.021	ns	ns
Years	28.79 a	23.56 b	10.77	10.49	1.16	1.17	0.15 b	0.16 a
Interaction								
S x N	ns	ns	ns	*	ns	ns	ns	**
S x H	ns	ns	ns	ns	ns	ns	ns	ns
N x H	ns	**	ns	ns	ns	ns	ns	ns
S x N x H	ns	ns	ns	ns	ns	ns	ns	ns

Means followed by different letters are significantly different from each other at 5% level of probability; *****: *Significant at 5% level of probability;* ******: *Significant at 1% level of probability;* **ns:** *Non-signifiant*

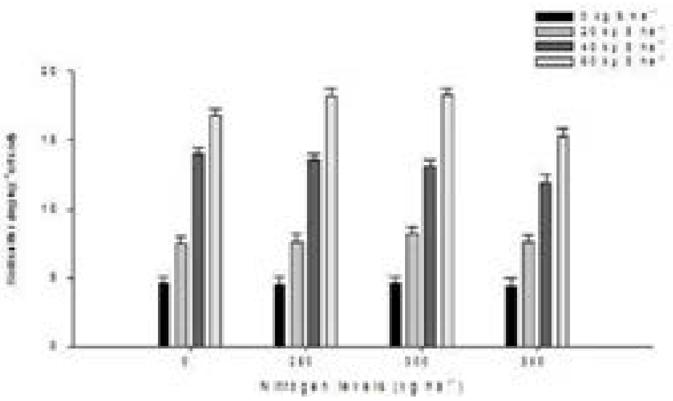

Figure 9: *Soil sulfur of maize hybrids grown with four levels of nitrogrn and sulfur*

Interaction of S x N was significant as shown in Figure 9. Nitrogen and sulfur being macro nutrients significantly affected the growth and development of crops and their interaction affected the concentration of both nutrients in soil and in plant tissue.

Tissue Analysis

Data regarding total nitrogen and sulfur in tissue indicated that both nitrogen and sulfur in tissue were significantly affected by nitrogen levels during 2013 and 2014, however, sulfur levels had a non-significant effect on nitrogen in tissue during 2013 (Table 3).

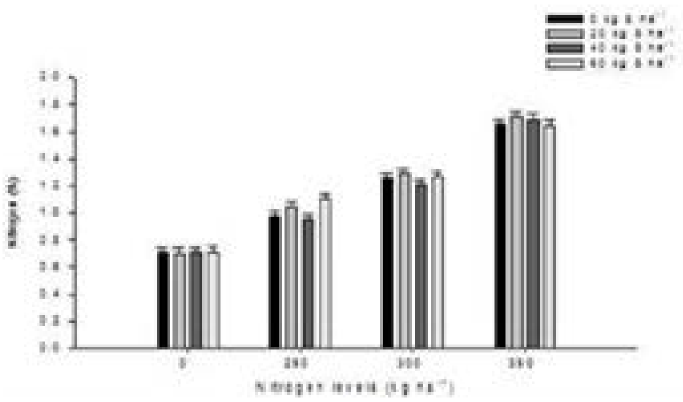

Figure 10: *Nitrogen status in tissue of maize hybrids grown with four levels of nitrogen and sulfur*

This might be ascribable to the fact that both N and S play role in biochemical processes, which contributed to more photosynthetic activities and thus resulted in the production of optimum assimilate for subsequent translocation to the plant parts for economic grain yield (Jaliya et al., 2013). Maize hybrids R-2210 had more values for N_{total} as compared to R-3305 and R-2207. Interaction of S x N and N x H were significant as shown in Figure 10 and 11, respectively, for 2014 only. S x N showed that both S and N interacted positively, but at 20 and 40 kg S ha^{-1}, a linear trend was observed at 350 kg N ha^{-1}. In case of N x H, R-2210 response was more significant statistically as compared to R-3305 and R-2207, respectively. The ratio of N_{total} to S_{total} content in plant tissues varies among plant species. The likely cause of this could be more mineralization and volatilization of N and moreover more N harvest in the second growing season. Nitrogen up-take is influenced by the optimum quantity of sulfur, and this up-take varied with the different amounts of fertilizers (Jaliya et al., 2013). The study of S interactions with N are directly important to all physiological and biochemical behaviour of crops, and hence needs more studies and research to find out the best combination of both these nutrients for economizing both maize crop yield and farmers' income (Jaliya et al., 2013; Jamal et al., 2010). Supply of S, however, significantly enhanced nitrogen in the tissue and in grain. Moreover, S deficiency in the soil contributes to mineral nitrogen losses through nitrate leaching (Lakkineni and Abrol, 1994). During 2014, value for S_{total} was more as compared to in 2013. Maximum value for $sulfur_{total}$ was analyzed in plots with all levels of N, except in unamended plots. However, S_3 and S_4 levels effect was statistically similar and more as compared to other levels of S. Interaction of sulfur with nitrogen was significant ($p < 0.01$) and both 40 kg and 60 kg S ha^{-1} had significantly varied effect on S_{total} with all levels of N, while at control S and 20 kg S ha^{-1}showed a decreasing trend for S_{total} (Figure 12). A routine of studies showed a significant S x N interaction in relation to the lineament of the harvest and grain production. N: S ratio has been accounted to be optimum (7.5:1) in grains, above which S might be deficient (Aulakh et al., 1980). There is a strong relationship between S and N content in plants. The ratio of N_{total} to S_{total} and protein determine the degree of availability of deficiency of S in protein. The N and S ratio are much preferred over concentration as a diagnostic criterion for S deficiency (Stewart and Whitefield, 1965). Kiros (2007) also found that N:S ratio substantially improved with higher N levels whereas lowered in S level for both leaves and grains. Khan et al. (1992) and Mandata et al. (1994) exhibited the S content in tissue enhanced for increasing S level. Likewise, increasing S application increases available SO_4-S in soil and the same was reported by Bharathi and Poongothai (2008) that higher SO_4-S content in soil with significant enrichment of S.

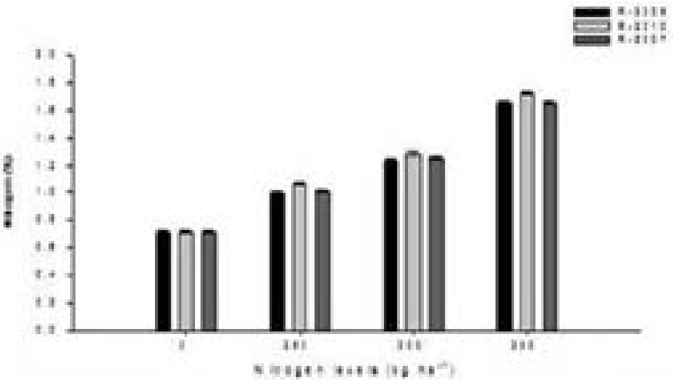

Figure 11: *Nitrogen status in tissue of maize hybrids grown with four levels of nitrogrn and sulfur*

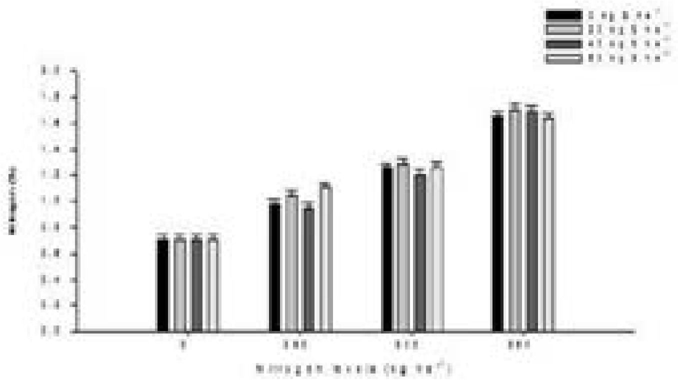

Figure 12: *Tissue nitrogen status of maize hybrids grown with four levels of nitrogrn and sulfur*

Economic Analysis

Economic analysis with respect to benefit cost ratio (BCR) is an important management strategy regarding fertilizers cost and output. The lowest values for net income and benefit cost ratio (BCR) were observed in control plots both for nitrogen and sulfur (N and S) and for all studied maize hybrids (Table 4). Plots where S was not applied with 350 kg N ha^{-1} had increased both net income and BCR linearly upto 143842/- (PKR) and 3.33, respectively for maize hybrid R-2210, followed by R-2207 with net income of 143108/- (PKR) and BCR value of 3.31. However, in control S, and with maximum level of N (350 kg ha^{-1}), the lowest values for net income (PKR. 131619) and BCR (3.05) was reported in plots with R-3305. Net income and BCR values for all corn hybrids increased with 350 kg N ha^{-1} and 40 kg S ha^{-1} of R-2210 upto 153798/- (PKR) and a BCR value of 3.41, followed by R-2207 with net income of 146390/- (PKR) and

Table 4: *Economic analysis (BCR) of maize hybrids as affected by nitrogen and sulfur*

N	S	H	Grain yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Grain value (PKR)	Stover value (PKR)	Gross income (PKR)	Total expenditure (PKR)	Net income (PKR)	BCR
0	0	H_1	2548	12943	56056	6472	62528	21500	41028	1.91
0	0	H_2	2598	13473	57156	6737	63893	21500	42393	1.97
0	0	H_3	2576	13300	56672	6650	63322	21500	41822	1.95
250	0	H_1	5471	22667	120358	11333	131692	35159	96533	2.75
250	0	H_2	5503	22633	121055	11317	132372	35159	97213	2.76
250	0	H_3	5509	20533	121187	10267	131454	35159	96295	2.74
300	0	H_1	6567	22267	144467	11133	155600	39180	116420	2.97
300	0	H_2	6948	23667	152856	11833	164689	39180	125509	3.20
300	0	H_3	6848	23233	150656	11617	162273	39180	123092	3.14
350	0	H_1	7444	22100	163772	11050	174822	43202	131619	3.05
350	0	H_2	8002	22000	176044	11000	187044	43202	143842	3.33
350	0	H_3	7980	21500	175560	10750	186310	43202	143108	3.31
0	20	H_1	2958	13300	65080	6650	71730	22300	49430	2.22
0	20	H_2	3036	13887	66799	6943	73743	22300	51443	2.31
0	20	H_3	3004	12992	66088	6496	72584	22300	50284	2.25
250	20	H_1	5451	21933	119918	10967	130885	36119	94766	2.62
250	20	H_2	5603	22067	123273	11033	134307	36119	98188	2.72
250	20	H_3	5592	20867	123031	10433	133465	36119	97346	2.70
300	20	H_1	6500	22333	143000	11167	154167	40140	114026	2.84
300	20	H_2	7340	23100	161480	11550	173030	40140	132890	3.31
300	20	H_3	6977	22850	153487	11425	164912	40140	124771	3.11
350	20	H_1	7455	21983	164010	10992	175002	44162	130839	2.96
350	20	H_2	8150	21500	179300	10750	190050	44162	145888	3.30
350	20	H_3	8107	22050	178354	11025	189379	44162	145217	3.29
0	40	H_1	2990	13000	65787	6500	72287	23590	48697	2.06
0	40	H_2	2980	13587	65567	6793	72361	23590	48771	2.07
0	40	H_3	2984	13090	65641	6545	72186	23590	48596	2.06
250	40	H_1	5443	22533	119735	11267	131002	37079	93923	2.53
250	40	H_2	5573	22900	122613	11450	134063	37079	96985	2.62
250	40	H_3	5536	20673	121788	10337	132125	37079	95046	2.56
300	40	H_1	6667	22167	146667	11083	157750	41100	116650	2.84
300	40	H_2	7100	22657	156200	11328	167528	41100	126428	3.08
300	40	H_3	7067	22800	155467	11400	166867	41100	125766	3.06
350	40	H_1	7467	22533	164267	11267	175533	45122	130411	2.89
350	40	H_2	8510	23400	187220	11700	198920	45122	153798	3.41
350	40	H_3	8198	22293	180365	11147	191512	45122	146390	3.24
0	60	H_1	2896	12300	63701	6150	69851	23970	45881	1.91
0	60	H_2	2978	12659	65505	6329	71834	23970	47864	2.00
0	60	H_3	2952	12346	64937	6173	71110	23970	47140	1.97
250	60	H_1	5549	22980	122082	11490	133572	38039	95533	2.51
250	60	H_2	5820	23833	128040	11917	139957	38039	101918	2.68
250	60	H_3	5759	21433	126702	10717	137418	38039	99380	2.61
300	60	H_1	6533	22460	143733	11230	154963	42060	112903	2.68
300	60	H_2	7433	22667	163533	11333	174867	42060	132806	3.16
300	60	H_3	7367	22933	162067	11467	173533	42060	131473	3.13
350	60	H_1	7600	23003	167200	11502	178702	46082	132619	2.88
350	60	H_2	8400	21490	184800	10745	195545	46082	149463	3.24
350	60	H_3	8138	22000	179025	11000	190025	46082	143943	3.12

H_1: *(R-3305);* **H_2:** *(R-2210);* **H_3:** *(R-2207); Grain price kg^{-1} (PKR. 22); stover price kg^{-1} (PKR 0.50)* a BCR value of 3.24. Moreover, with 350 kg N ha^{-1} and 60 kg S ha^{-1}, net income and BCR values for all corn hybrids declined. Net income and BCR values were lowest in control plots i.e. 41028/- (PKR), 1.91 for R-3305, 42393/- (PKR), 1.97 for R-2210 and 41822/- (PKR), 1.95 for R-2207, respectively. Modern and intensive agronomic practices along with best nutrient management strategies not only improved yield but also BCR (Aurangzeb et al., 2007). It could be due to the fact that application of higher levels of N and S increased maize yield and ultimately more net income and BCR was obtained (Rehman et al., 2011) as compared to control plots. These results were accordance to the findings of Memon et al. (2013) who found that maximum level of input in the form of nitrogen has resulted more grain yield and hence, more benefit. Rasheed et al. (2003) also reported that each nutrient added cost but ultimately enhanced yield and BCR values.

Conclusion

It is concluded that maize hybrids responded positively to higher rates of N in term of biological yield, grain yield, harvest index, benefit cost ratio whereas application of sulfur at either level had not substantial improvement in yield and yield related traits except S content in soil and in tissue. Nitrogen level of 350 kg ha^{-1} substantially increased maize yield with the highest values of BCR as compared with other N levels. The combine application of N and S at rate of 350 kg ha^{-1} with 40 kg ha^{-1} was found more economical as compared to other levels.

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Authors' Contribution

This research article is a part of first author's (Abdul Qahar) PhD dissertation. Prof. Dr. Bashir Ahmad, Department of Agronomy, The University of Agriculture, Peshawar, is my PhD supervisor and he guided me in all research activities technically and practically. Dr. Shahen Shah (Major member) and Dost Muhammad (Minor member) are my committee members and they helped me in thesis write up and soil analysis of my research data.

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