Pak. J. Bot., 45(2): 435-442, 2013.

RESPONSE OF SOIL AND FOLIAR APPLIED NITROGEN AND SULFUR TOWARDS YIELD AND YIELD ATTRIBUTES OF WHEAT CULTIVARS

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Abstract

A field experiment was conducted to study the effect of soil and foliar application of nitrogen and sulfur on wheat varieties during two growing seasons (2008-09 and 2009-10) at New Developmental Farm of Khyber Pukhtunkhwa Agricultural University Peshawar, Pakistan. The experimental setup was Randomized Complete Block Design with four replications. The 5 × 3 factorial experiment was designed with eight different nitrogen and sulfur treatments and were applied to main plots at four application timings (T1 = at sowing , T2 = at tillering, T3 = at anthesis and T4 = after anthesis stages). Number of spike m^{-2}, Number of grains $spike^{-1}$, 1000 grain weight and grain yields increased significantly by both N and S application methods. Wheat yield and yield components were higher when nitrogen and sulfur were applied in split doses at sowing (N @ 60 kg ha^{-1} + S @ 15 kg ha^{-1}), tillering (N @ 40 kg ha^{-1}), at anthesis (N @ 10 kg ha^{-1} + S @ 10 kg ha^{-1}). It is concluded that N and S spray at the rate of 10-15% during different growth stages would improve the grain yield and yield components of wheat in the study area and contributed significantly to increased production.

Introduction

Several potential benefits of providing nitrogen to cereals via the foliage is in practice now days. As urea solution include reduced N losses through denitrification and leaching, compared with direct N applications to the soil. Foliar urea applications have increased grain yield, particularly when applied before flag leaf emergence and when N availability was limiting (Gooding & Davies, 1992). Applications of N near flowering increased post flowering N uptake, grain protein content, and grain protein concentration. Increases in grain N content were often larger when applications of N fertilizers to the soil were reduced, and when the urea solution was sprayed either at anthesis or during the following two weeks (Gooding & Davies, 1992; Iftikhar *et al.,* 2010; Babar *et al.,* 2011). A supplemental dose of 7 kg N ha^{-1} as urea spray significantly increased maize grain yield (Singh *et al*., 2003). Grain and stover yields were unaffected by the spray treatment apparently because plants were unable to utilize the urea N applied to the vegetation (primarily leaves) after anthesis to enhance or extend the accumulation of dry matter by either eared or earless plants (Singh *et al*., 2003). Foliar applications of urea to chlorotic leaves of N-deficient maize restored both normal chlorophyll content and stomatal behavior of leaves. Increases in N levels significantly increased plant height, ear length, and diameter, number of kernel row^{-1} and seed weight (Debatz, 2000; Maqsood *et al*., 2012). Grain weight per ear and total grain weight increased with an increase in N rate at high density (Gab- Allah, 2005). Application of half N as basal and half N as foliar spray at growth stage 3 increased the grain yield of maize by 43 percent compared to that obtained by applying N and S content of wheat influence the bread making quality of flour (Zhao *et al*., 1999). Foliar application of N as well as soil application of N and S on wheat at optimum timings (at and after anthesis) have increased grain protein content and improved bread making qualities (Luo *et al*., 2000). Currently in most of the countries, S has been identified as a limiting factor for crop quality, although wheat has a relatively low sulfur requirement (Zhao *et al*., 1999). Low sulfur content in flour increased dough strength and reduced dough extensibility (Mac Ritchie & Gupta, 1993). In terms of disease control foliar application of S increased the effectiveness of fungicide (Zahid & Leitch, 2005). Soil application of S fertilizers increases gel protein weight in flour and the proportion of polymeric protein (Zhao *et al*., 1999). Responses of bread making quality of wheat to S are more common than responses in terms of grain yield. S application did not affect grain protein concentration directly, but tended to increase gel protein weight in flour and the proportion of polymeric proteins. S deficiency decreases grain size and baking quality because of formation of disulfide bonds formed from the sulphydryl groups of cysteine. This affects the viscoelasticity of dough (Gyori, 2005). The baking quality of wheat was improved by S application, showing high correlation between loaf volume and the S content of grain and thus improving rheological properties of dough (Singh, 2003). Sulfur deficit may result in harder grains and the dough made from such grain is usually stiff and is not elastic (Ryant & Hrivna, 2004). The total uptake of N and S, and the concentration of N and S in the grain were increased when S was applied (Zahid & Leitch, 2005).

Studies on the proper combination of levels and timings of urea and sulfur spray and soil application in the agro-ecological wheat growing zones of the Khyber Pukhtunkhwa, Pakistan have not been carried out. To exploit the full potential benefits of foliar and soil applied urea and sulfur application to wheat, more needs to be known about the mechanisms, and how to prevent losses of N and S from the foliage, and to reduce the phototoxic influences of sprays. The present study was, therefore, initiated to determine the best level and timing of foliar application of N and S on wheat to increase yield and maximize the net income of the farmers.

Materials and Methods

Experiment was conducted at New Developmental Farm of KP Agricultural University Peshawar, during 2008-09 and 2009-10. Soil of the experimental site is clay loam, low in nitrogen (0.03-0.04%), low in organic matter (0.8-0.9%), extractable phosphorus (6.57 mg kg^{-1}), exchangeable potassium (121 mg kg^{-1}) and alkaline in reaction with a pH of 8.0-8.2 (Amanullah *et al*., 2009). A basal dose of TSP (100 kg P/ha) and MOP (50 kg K/ha) was applied at sowing. Urea was applied as a source for N and ammonium sulphate was applied as a source for S. In which half dose of urea and ammonium sulphate was applied at the time of sowing and the remaining half dose of both was applied at different growth stages. The experiment was laid out in RCB Design having four replications. Subplots size was 5m x 3m having 10 rows 5m long and 30cm apart. Two varieties Pirsabaq- 2005 and Khyber-87 were used.
Details of the treatments are as follows:

1. **Control Treatment**
2. **Recommended treatment** (60 kg N/ha at sowing + 60 kg N/ha at tillering)
3. **Soil applied N** (60 kg N/ha at sowing + 40 kg N/ha at tillering + 10 kg N/ha anthesis +10 kg N/ha after anthesis)
4. **Soil + Foliar applied N** [60 kg N/ha at sowing + 40 kg N/ha at tillering + 10 kg N/ha at anthesis (foliar) +10 kg N/ha after anthesis (foliar)]
5. **Soil applied S** (15 kg S/ha at sowing + 10 kg S/ha at anthesis + 5 kg S/ha after anthesis)
6. **Soil + foliar applied S** [15 kg S/ha at sowing + 10 kg S/ha at anthesis (foliar) + 5 kg S/ha after anthesis (foliar)]
7. **Soil applied N + Soil applied S** (combination of treatment number 3 and treatment number 5)
8. **Soil + Foliar applied N + Soil + Foliar applied S** (combination of treatment number 4 & treatment 6**)**

Number of grains $spike^{-1}$ was calculated by selecting five spikes randomly in each sub plot. Grains were separated and counted, and then average number of grain $spike^{-1}$ was calculated. Biological yield was calculated by harvesting two central rows in each sub plot and after drying the bundles were weighted and then converted it into biological yield kg ha^{-1}. Incase of thousand grain weight 1000 grains were randomly picked from each sub plot and weighed with digital balance in grams. The bundles selected for biological yield were threshed, cleaned and weighed by balance and then was converted to grain yield kg ha^{-1}. Harvest index was calculated by dividing grain yield by biological yield.

Statistical analysis: All data are presented as mean values of four replicates. Data were analyzed statistically for analysis of variance (ANOVA) following the method described by (Gomez & Gomaz, 1984). MSTATC computer software was used to carry out statistical analysis (Russel & Eisensmith, 1983). The significance of differences among means was compared by using LSD test (Steel & Torrie, 1997).

Results and Discussion

It is obvious from the data that number of spikes m^{-2} was significantly affected by different treatment combinations of both S and N at different growth stages. Control treatment produced maximum numbers (331) of spikes m^{-2} shown in Table 1. It may be due to the fact that the control plots already have some nutrients which support the spike production. But these results are in against with those of many scientists who proposed that both N and S application at different growth stages have the capability to obtained optimum yield of wheat i-e full at sowing (Iqbal, 1982), full at heading (Holliday, 1960) and split application at sowing, tillering and heading (Sarkar *et al*., 1990). While minimum number of spikes was produced by the plot applied with T_6 (S @15kg ha^{-1} at sowing + 10 kg ha^{-1} at anthesis and 5 kg ha^{-1} after anthesis). The concern data also showed that maximum number of spikes m^{-2} (283) was produced by Khyber-87 as compared with Pirsabaq-2005 presented in Table 1. Results also found significant association between the interaction of fertilizer treatments and varieties. From the results of planned comparison of different treatments of the two varieties it was observed that recommended dose of N vs. other fertilizers as well as no fertilizer vs. fertilizers comparison showed highly significant result (Fig. 1). It may be due to the fact that N is very important constituent for vegetative growth hence contributed maximum number of spikes. The results of planned comparison also reported significant relationship between soil applied urea vs. soil+ foliar applied urea presented in (Fig. 1). It may be due to the fact that foliar application of N enhanced number of spikes m^{-2}. Similar results were presented by Siddiqui *et al*., (2008). Similarly the results of the planned comparison of the two varieties showed that the S alone effect was also significant (Fig. 1). The probable reason may be due to the maximum availability and absorption of S in case of foliar spray resulted in more grains $spike^{-1}$. These results are supported by Bly & Woodard, (2005) who stated that higher grain yield by S application in equal splits was mainly due to higher 1000 grain weight and number of spikes m^{-2}. Significant differences in number of grains $spike^{-1}$ were found among different treatments of S and N combinations (Table 1). Maximum number of grains $spike^{-1}$ (84 nos.) was found in T_7 [N @ 60 kg ha^{-1} at sowing + 40 kg ha^{-1} at tillering +10 $kgha^{-1}$ at anthesis + 10 $kgha^{-1}$ after anthesis] + [S @15 kg ha^{-1} at sowing + 10 kg ha^{-1} at anthesis + 5 kg ha^{-1} after anthesis]. It might be due to the efficient utilization of S and N which enhanced metabolism and meristimatic activities and yield components. While minimum number of grains $spike^{-1}$ (69 nos.) was found in control treatment.

Table 1. Effects of various N and S fertilizer treatment combinations on yield and yield components of two varieties of wheat.

Fertilizer treatments	No. of spikes m^{-2}			No. of grains $spike^{-1}$			Biological yield (Kg/ha)			Grain yield (Kg/ha)			1000 grain weight (g)			Harvest index (%)		
	Varieties			Varieties			Varieties			Varieties			Varieties			Varieties		
	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean
Control treatment (T1)	341	321	331a	73	67	70d	9680	6944	8312e	2461	2409	2435f	56	42	49d	24	24	24h
Recommended dose (T2)	291	310	301a	73	83	78b	9666	9749	9707b	2718	2641	2679e	61	47	54c	28	26	27g
Soil applied N (T3)	243	282	263c	73	73	73c	8805	9833	9319b	3450	3440	3445d	56	57	56b	34	35	34f
Soil & foliar applied N (T4)	214	336	275b	63	83	73c	7221	9971	8596c	3558	3557	3557d	54	47	50d	36	37	36e
Soil applied S (T5)	349	210	280b	73	65	69e	10791	9041	9916b	3861	3733	3797c	56	44	50d	44	43	43d
Soil and foliar applied S (T6)	290	178	234d	73	77	75b	10749	7194	8972c	941	3758	3850c	60	60	60a	46	46	46c
Combination of T3 & T5 (T7)	222	313	268c	74	97	84a	11763	10138	10951a	4454	4433	4443b	56	66	61a	53	56	54b
Combination of T4 & T6 (T8)	228	308	268c	62	70	66f	983	10124	9319b	4686	4602	4644a	55	52	54c	56	58	57a
Mean	272	283	-	71	76	-	9814	9124	-	3654	3572	-	57	52	-	40	41	-
2008-09	274	282	278	70	76	73	10319	9635	9977	3672	3632	3652	57	52	54	40	41	40
2009-10	270	282	276	71	76	73	9308	8614	8961	3610	3512	3512	57	52	54	40	40	40
LSD																		
Fertilizer treatments	40.03			4.1			1112			143.8			1.8			1.6		
V x F	40.03			5.9			786			-			2.6			-		
Interactions	**P- V**			**P- V**			**P- V**			**P- V**			**P- V**			**P- V**		
Y x F	0.78			1.0			0.99			0.66			1.0			0.85		
Y x V x F	0.99			1.0			0.99			0.33			1.0			0.76		

Mean of the same category followed by different letters are significantly different ($p \geq 0.05$) using LSD test
V1 = Pir Sabaq-2005
V2 = Khyber-87
Y = Year
F = Fertilizer Treatments
V= Variety
LSD = Least Significant Difference

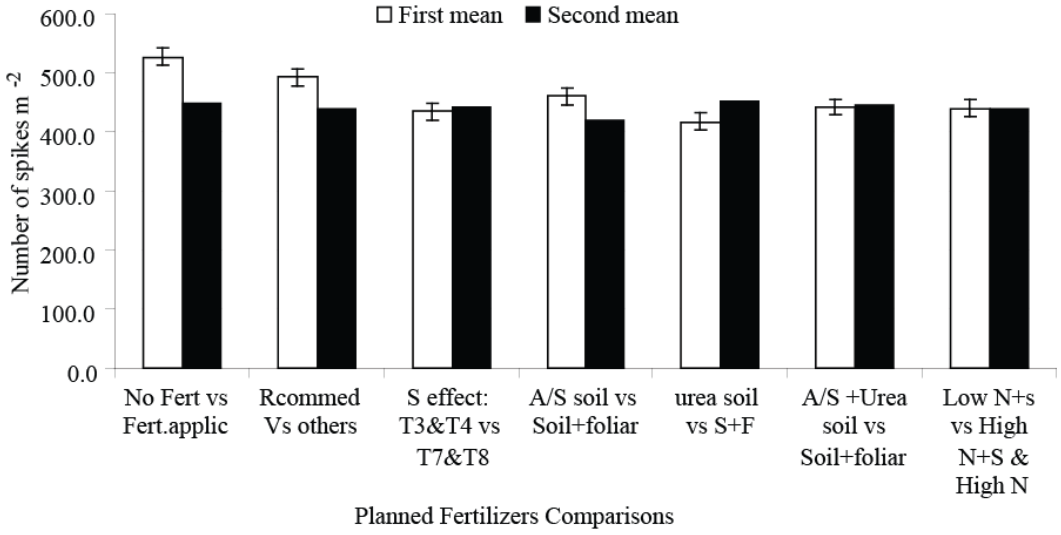

Fig. 1. Planned mean comparisons of number of spikes m^{-2} of wheat cultivars as influenced by N and S fertilization during 2008-09 & 2009-10.

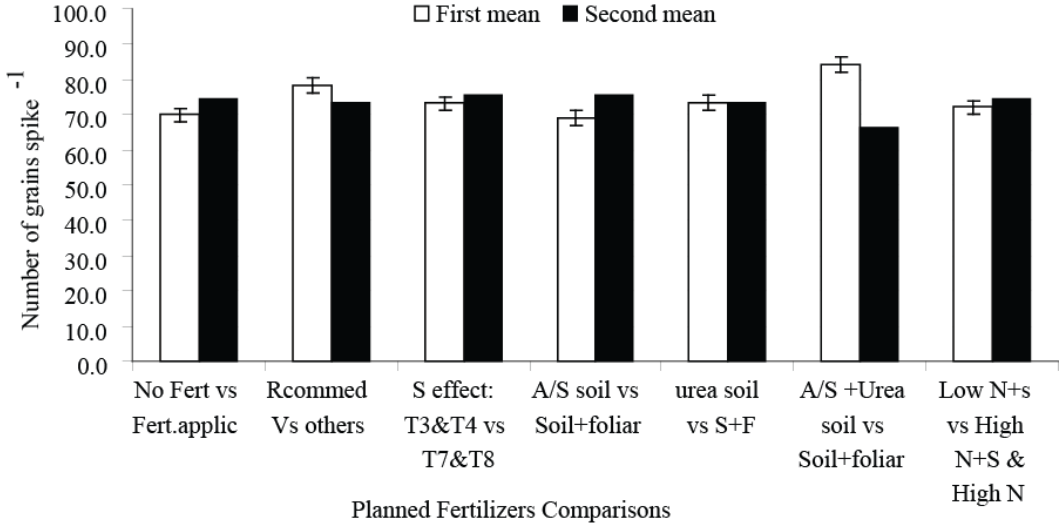

Fig. 2. Planned mean comparisons of number of grains $spike^{-1}$ of wheat cultivars as influenced by N and S fertilization during 2008-09 & 2009-10.

These results are in line with those of Luo *et al*., (2000) who reported that application of N and S on wheat at optimum timings (at and after anthesis) have increased number of grains $spike^{-1}$. Similarly both the varieties of wheat also presented highly significant effect. Khyber-87 produced highest number of grain $spike^{-1}$ (77 numbers). The findings of the results also reported significant relationship of variety and fertilizer treatments combination interaction with number of grains $spike^{-1}$. The possible reason might be due to that both S and N application on various growth stages either as foliar spray or through soil applied produced favorable environment for production of fertile tillers and proper nourishment of the crop which led to high grain yield. These results matched with those of Coale *et al*., (2002) who investigated maximum grains through application of S and N. From the means of planned comparison of two varieties also showed that recommended dose vs. other fertilizers treatment as well as no fertilizers vs. fertilizer treatment also showed significant result (Fig. 2). These results are in line with Zhao *et al*., (1999) who observed that N and S contents of wheat influence the bread making quality of wheat. Means of planned comparison of two varieties also observed that S alone effect on number of grains $spike^{-1}$ showed significant relationship (Fig. 2). It might be due to that S foliar application at anthesis stage enhanced grain yield. Similar results were observed by Kratochvil, (2005) who suggested continuous need for S supply in wheat for high grain yield. The presented results revealed that different treatments of N and S combinations have significant affect on biological yield (Table 1). Maximum biological yield of (10950.75 kg/ha) was obtained from T_7 [60 kg/ha N alone at sowing + 40 N kg/ha N at tillering + 10 kg/ha N at anthesis + 10

kg/ha N after anthesis] + [15 kg/ha of Sulfur alone at sowing + 10 kg/ha at anthesis stage + 5 kg/ha after anthesis stage]. This may be due to the efficient response of wheat crop to N which produced more number of total tillers which ultimately increased biological yield. Also the increased in biological yield might be due to the response of wheat crop to urea at vegetative growth stage. While minimum biological yield (8311.688 kg/ha) was showed by control treatment. Similarly the effect of both the varieties of wheat also generated significant results. Pirsabaq-2005 produced maximum biological yield (9813.50 kg/ha) as compared with the second variety. The reason might be that Pirsabaq-2005 is more responsive to N and S utilization. The interaction between variety and fertilizer was also found significant. From the means of planned comparison of the two varieties also showed that the interaction between no fertilizers vs. fertilizers application as well as the comparison between recommended doses vs. other treatments application was observed significant (Fig. 3). The probable reason may be that biological yield of wheat increased with foliar application of different nutrients individually or in combination. Such results were also presented by Soylo, (2005). Likewise planned comparison of different fertilizer treatments also proposed that the comparison of soil applied ammonium sulphat and urea vs. soil + foliar application of both presented significant association (Fig. 3). Similarly from the means of planned comparison of two varieties showed that alone sulfur effect on biological yield was also found significant (Fig. 3). It may be due to that sulfur is a readily available nutrient and it cannot remain in the soil for longer time and so utilized efficiently. These results were in agreement with the results of Soleimani, (2006) who investigated an increased in biological yield with foliar and soil application of S. Likewise the effect of urea soil applied vs. soil+ foliar applied also gave significant result. The data about grain yield (Table 1) showed that grain yield increased significantly with foliar as well as soil application of both S and N. Maximum grain yield (4644 kg/ha) was produced by T_8 [N @ 60 kg ha^{-1} nitrogen at sowing + 40kg ha^{-1} nitrogen at tillering + 10 kg ha^{-1} nitrogen at anthesis (spray) and 10 kg ha^{-1} nitrogen after anthesis (spray)] + [S @15kg ha^{-1} at sowing +10 kg ha^{-1} at anthesis (spray) + 5 kg ha^{-1} after anthesis (spray)]. It may be due to the efficient utilization of S as well as N which improve fertility of the concerned plots. The high grain yield may also be due to the more number of productive tillers, while minimum yield was obtained in control treatment (2435.063 kg/ha). Sulfur does not affect only N utilization and grain quality, but it also play an important part in the formation of baking quality (Ryant & Hrivna, 2004). The data also presented that Pirsabaq-2005 yielded higher grain yield (3654 kg/ha). From the means of planned comparison of two varieties it was found that the interaction between no fertilizers vs. fertilizer comparison showed significant results (Fig. 4). The probable reason might be that both N and S fertilizers applied at anthesis stage have significant effects on the absorption of N and S through the leaves and their translocation to grains, which in turn can influence flour and dough properties. Such arguments are linked with the findings of Tea, *et al*., (2007) who proposed that N and S application either as foliar spray or as soil applied at different growth stages enhanced the quality of grain as well as flour. Similarly the interaction between recommended fertilizers vs. other fertilizers combination also gave significant results (Fig. 4). It was also found from the means of planned comparison that S alone effect on grain yield was also highly significant (Fig. 4). The reason may be that grain and bread-making quality correlated more closely with grain S concentration than with grain N concentration. These results matched with the results of McGrath, (2003). Similarly the interaction between soil applied ammonium sulphate vs. soli + foliar applied ammonium sulphate was also found significant (Fig. 4). Data regarding 1000 grain weight is presented in Table 1. The concern data revealed that application of N and S resulted a significant increase in 1000 grain weight. T_7 [N @ 60 kg ha^{-1} at sowing + 40kg ha^{-1} at tillering +10 kg ha^{-1} at anthesis + 10 kg ha^{-1} after anthesis] + [S @15kg ha^{-1} at sowing + 10 kg ha^{-1} at anthesis + 5 kg ha^{-1} after anthesis] yielded heavier grains (61 g). The heavier grain weight may be due to the efficient metabolic activities which increased the gluten and moisture contents in grain and so the weight of grain increased. These results are in conformity with those of Soylu *et al*., (2005) who reported significant increase in 1000 grain weights with the application of N and S, while control treatment produced grains of lesser weight (49.238 g). Likewise both the varieties also showed significant results. Pirsabaq-2005 produced maximum weight of 1000 grains (57 g) as compared with the other variety. The reason might be due that Pirsabaq-2005 variety is more responsive to S and N effect also this variety has the potential to produced high grain yield. Likewise the interaction between varieties and fertilizers effect was also found significant. It was also observed from the means of planned comparison of the two varieties that no fertilizer vs. fertilizers treatment gave significant effect (Fig. 5). The reason may be that when wheat was fertilized only with N it meets the required need up to limited extent but when S was applied in addition to N then the yield quality parameters improved. Similar results were produced by Podlesna & Cacak, (2008) who reported that wheat fertilization with S and N affects S content and N: S ratio in grain. Similarly the comparison between recommended vs. other fertilizes also showed significant result (Fig. 5). Means of planned comparison also reported that the effect of S alone was also found highly significant (Fig. 5). This result could be due to inherently low levels of S in the concern research area. The positive response of wheat crop to S is also justified by Jarvan & Adamson, (2005) who reported that wheat starts suffering more and more from S deficiency, and that S fertilization during the growing season considerably enables an increase in the yielding ability. Some other treatment comparisons like soil applied ammonium

sulfate vs. soil and foliar applied ammonium sulfate gave significant result. Similarly the comparison between soil applied urea vs. soil and foliar applied urea was also found significant. In case of harvest index the presented data revealed that soil and foliar application of both N and S resulted a significant increase in the concern parameter (Table 1). T_8 [N @ 60 kg ha^{-1} nitrogen at sowing + 40kg ha^{-1} nitrogen at tillering + 10 kg ha^{-1} nitrogen at anthesis (spray) and 10 kg ha^{-1} nitrogen after anthesis (spray)] + [S @15kg ha^{-1} at sowing +10 kg ha^{-1} at anthesis (spray) + 5 kg ha^{-1} after anthesis (spray)] showed maximum harvest index (57 %). The increased in harvest index might be due to the increased grain yield in the concerned plots to which treatment number-8 was applied which ultimately showed higher harvest index, while control treatment showed minimum harvest index (24.014%). It was also observed from the data that Khyber-87 produced high harvest index (40.45%) (Table 1) as compared with the other variety. While the interaction between fertilizer treatments and varieties presented non significant relationship. From the means of planned comparisons of two varieties it was found that no fertilizer vs. fertilizer comparison and also recommended dose vs. other fertilizers comparison gave significant results. These results reflected the observations of Guenis *et al*., (2003) who reported that the utilization of fertilizers especially urea applied through soil is not as effective as, when it is supplied to the plants through foliage along with soil application. Mean of planned comparison also showed that the effect of S alone was also found significant (Fig. 6). These results are similar with the results of Puri, (1997) who reported that soil as well as foliar application of S increased the harvest index by 10-20% in winter wheat. Likewise the comparison between soil applied urea vs. soil+ foliar applied urea also presented significant observations (Fig. 6).

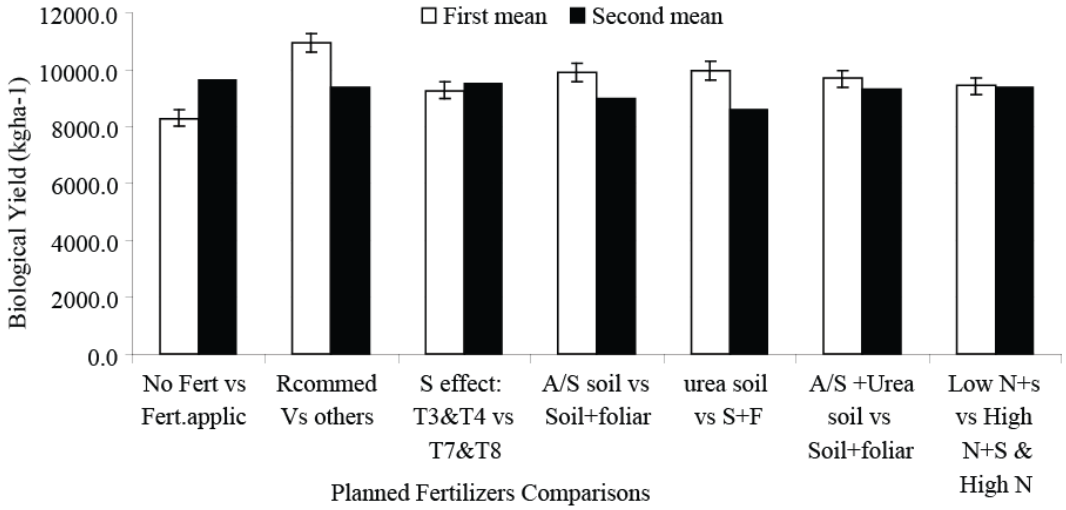

Fig. 3. Planned mean comparisons of biological yield (kg/ha) of wheat cultivars as influenced by N and S fertilization during 2008-09 & 2009-10.

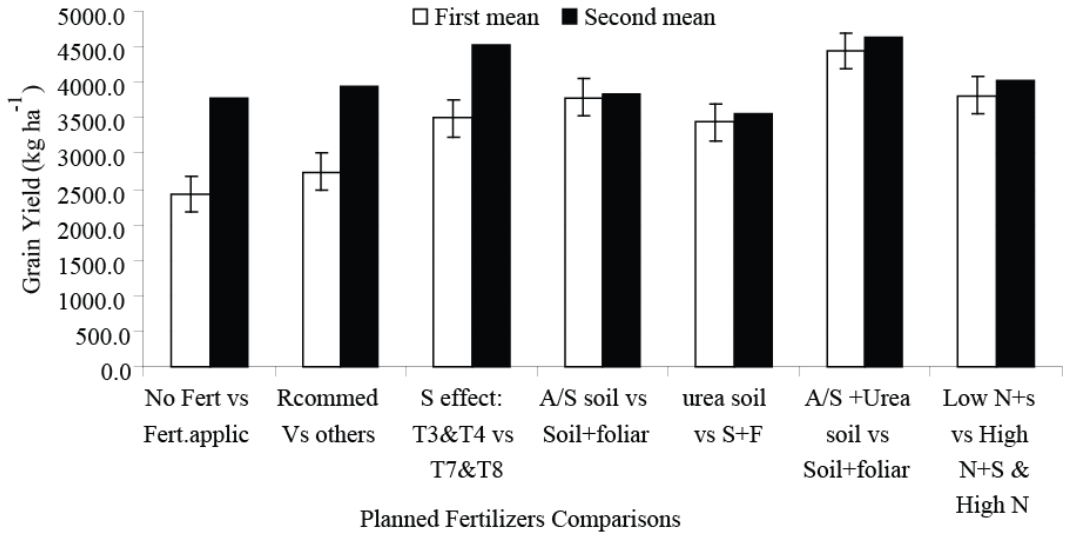

Fig. 4. Planned mean comparisons of grain yield (kg/ha) of wheat cultivars as influenced by N and S fertilization during 2008-09 & 2009-10.

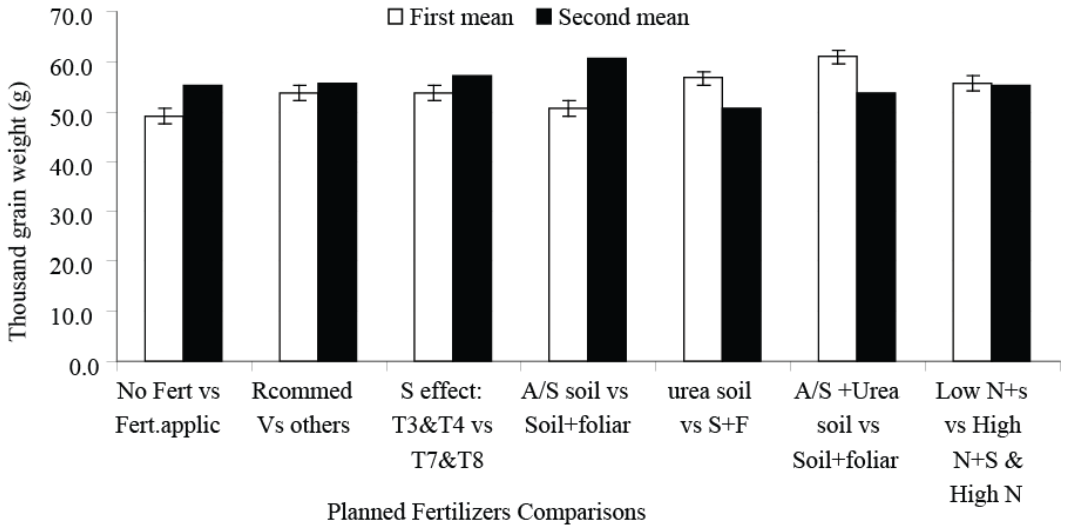

Fig. 5. Planned mean comparisons of 1000 grain weight (g) of wheat cultivars as influenced by N and S fertilization during 2008-09 & 2009-10.

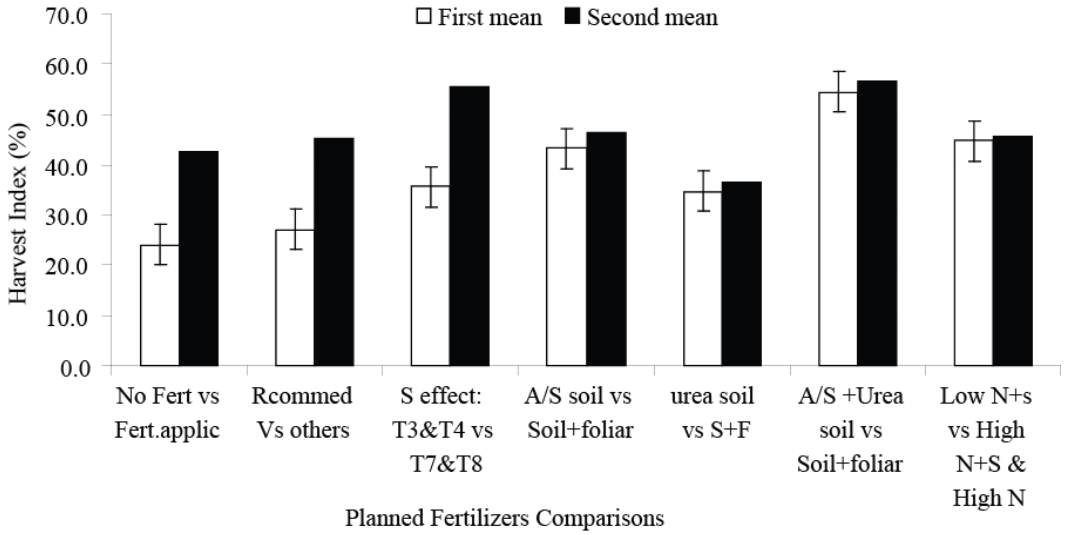

Fig. 6. Planned mean comparisons of harvest index (%) of wheat cultivars as influenced by N and S fertilization during 2008-09 & 2009-10.

Conclusion

- The current study revealed a significant yield and yield components response to N and S combinations.
- Soil and foliar applied N and S increased grain yield of wheat cultivars.
- Control practice has no contribution to yield and yield components of wheat.

Acknowledgments

The main author (BS) is thankful to Higher Education Commission (HEC) who awarded me scholarship under Indigenous scholarship scheme batch-5 for completion of my Ph.D. program and also provides me the opportunity to visit China under IRSIP scholarship. Our cordial thanks are also due to Zhejiang University, China for providing services to write this manuscript. We are also thankful to my parent institute KP Agricultural University Peshawar, Pakistan for their support to conduct this research.

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(Received for publication 22 August 2011)