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GROWTH FACTORS AND STRAW YIELD OF WHEAT CULTIVARS IN RELATION WITH NITROGEN AND SULFUR FERTILIZATION

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ABSTRACT

This research was carried out to estimate the effects of sulfur and nitrogen application both as soil as well as foliar fertilization on growth factors and straw yield of wheat cultivars. An experiment was conducted at New Development Farm (NDF) of Khyber Pukhtunkhwa Agricultural University, Peshawar, Pakistan during 2008-09 and 2009-10. Eight different N and S treatment combinations were applied at various growth stages. Two wheat varieties, Pirsabaq-2005 and Khyber-87 were used. The experiment was laid out in randomized complete block design with four replications. Different treatment combinations of nitrogen and sulfur significantly affected almost all agronomic characteristics and yield components of wheat cultivars. Soil + foliar applied N and soil+ foliar applied S gave non significant relationship with seedling emergence. Both the cultivars gave same number of seedling emergence. Khyber-87 gave maximum total number of tillers m^{-2}. Treatment number-3 (soil applied N) reported maximum plant height. Pirsabaq-2005 produced maximum plant height. Days to flowering and days to physiological maturity showed no significant interaction with fertilizer treatment combinations. Khyber-87 took more days to physiological maturity, while pirsabaq-2005 produced maximum straw yield. Maximum straw yield was observed by the fertilization of treatment number-8 (Soil+ Foliar applied N and Soil+ Foliar applied S) while control treatment was recorded with low straw yield. From the results of means of planned comparison of the two varieties it was proposed that in agronomic study all the observations except days to flowering and days to physiological maturity showed significant association with sulfur alone treatment, no fertilizer vs. fertilizer comparison and recommended practice vs. others comparison. Likewise reports from the means of planned comparison showed that the sulfur presented significant relationship with yield and yield component study. Therefore, it is concluded that soil and foliar application of nitrogen @ 100-120 kg N/ha and sulfur @ 20-35 kg S/ha in split doses at various growth stages can be practiced to get appreciable growth and yield of wheat crop.

Keywords: wheat cultivars, growth factors, straw yield, foliar applied N and S, soil applied N and S.

INTRODUCTION

Wheat (*Triticum aestivum* L.) is the most widely cultivated of all the cereal and is the major source of nourishment. Wheat requirements in Pakistan are growing at an exorbitant rate due to its rapid expansion in population. Balance use of fertilizers and agronomic measures are needed to raise production of this crop. The role of macro and micro nutrients is crucial in crop nutrition for achieving higher yields (Raun and Jhonson, 1999). The soils of Pakistan are deficient in N and are supplemented with chemical fertilizers for enhancing crop productivity. Balanced nutrition is an essential component of nutrient management and plays a significant role in increasing crop production and its quality. For the major processes of plant development and yield formation the presence of nutrients like N, P, K, S and Mg etc in balance form is essential (Randhawa and Arora 2000).

N is the motor of plant growth and makes up 1 to 4% of dry matter of the plants (Anonymous 2000). N is the component of protein and nucleic acid and when N is sub-optimal, growth is reduced (Haque, *et al*., 2001). Efficient remobilization of urea (N) to the grain after foliar fertilization on wheat at optimum timings, i.e., at and after anthesis stage, has been shown to increase grain protein content and improve bread-making quality (Tea, *et al*., 2007).

N as well as S are utmost important constituents of plant proteins and are required throughout the crop growth period from vegetative stage to subsequent harvesting. The incidence of S deficiency has increasingly been reported in cereal crops in Asian countries over the last decade. The Sulfur Institute of Washington has estimated that the annual S fertilizer deficit worldwide will increase from a current level of 8 million tones to over 11.5 million tones by 2012. It is therefore not surprising that interest in S has increased greatly in the recent years. Decreasing S deposition from the air, and the use of more concentrated phosphate fertilizers that contain less S has led to reports of S deficiencies in wheat. S deficiency significantly effects the production and quality of wheat (McGrath, 2003; Gyori, 2005). Without adequate S, crops can't reach their full potential in terms of yield, quality or protein content; nor can they make efficient use of applied N (Sahota, 2006). At high N fertilization levels significant responses to S fertilization were found which emphasized the need for precision application of S in intensive wheat production systems. Continued use of N fertilizer without supplemental S on low S soils will reduce flour quality (Flaete, *et al*., 2005). S does not affect only N utilization and grain quality, but it also plays an important part in the formation of the baking quality (Ryant and Hrivna, 2004). Limiting S availability has been shown to favor the synthesis and accumulation of low S storage proteins at

the expense of S rich proteins (Zhao, *et al*., 1999a; Flaete *et al*., 2005). The response fraction is known to play the most essential role for bread-making. Mature wheat grains contain 8-20% proteins. The gluten proteins, the gliadins and glutenins, constitute up to 80-85% of total flour proteins, and confer properties of elasticity and extensibility that are essential for functionality of wheat flours (Kuktaite, 2004).

Foliar fertilization, that is nutrient supplementation through leaves, is an efficient technique of fertilization which enhances the availability of nutrients. Foliar application of N and S at different growth stages of wheat enhanced the flour and bread-making quality of wheat; differences in N and S uptake through foliar application and redistribution of N and S in wheat may influence protein content and composition as well as grain characteristics and dough properties (Tea, *et al*., 2007). The metabolism of N and S are closely interrelated and an optimal N/S ratio in grain has been shown to improve bread-making quality.

The study under report was therefore designed to investigate about the growth factors and straw yield of wheat cultivars in relation with nitrogen and sulfur fertilization.

MATERIALS AND METHODS

Site description and experimental design

Experiment was conducted at New Developmental Farm of Khyber Pakhtunkhwa Agricultural University Peshawar, Pakistan 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 P (100 kg/ha) and K (60 kg/ha) was applied at sowing. Urea was applied as a source for nitrogen and ammonium sulphate was applied as a source for sulfur. 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.

Fertilizer treatments

Details of the fertilizer treatments are as followed:

a) Control
b) Recommended dose of N (60 kg N/ha at sowing + 60 kg N/ha at tillering)
c) 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)
d) 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)]
e) Soil applied S (15 kg S/ha at sowing + 10 kg S/ha at anthesis + 5 kg S/ha after anthesis)
f) Soil + foliar applied S [(15 kg S/ha at sowing + 10 kg S/ha at anthesis (Foliar) + 5 kg S/ha after anthesis (Foliar)]
g) Soil applied N + Soil applied S (combination of treatment no. 3 + treatment no. 5)
h) Soil and foliar applied N + Soil and foliar applied S (combination of treatment no. 4 + treatment 6)

Days to seedling emergence were recorded in each subplot when 75% plants emerged. Number of days was counted from the date of sowing to the date of 75% plants emergence in all plots. Data on total number of tillers m^{-2} was recorded by counting tillers in 2 randomly selected samples of 1m row from each subplot at tillering stage and was converted into tillers m^{-2}.

$$\text{Tillers } m^{-2} = \frac{\text{Counted tillers in two rows}}{\text{R-R x row length x no. of rows}} \times 1\ m^2$$

Days to flowering were calculated from the date of sowing till the date when 50% of the plants produced their spikes. Days to physiological maturity data was recorded when 90% of the spikes got matured by counting number of days from sowing till physiological maturity. Complete loss of green color from the glumes and peduncle was used as criteria for physiological maturity. Plant height (cm) was recorded from ground level to the top of spike of 5 randomly selected tillers in each sub plot and was averaged. Straw yield was calculated from the difference between biological yield and grain yield.

Statistical analysis

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

RESULTS AND DISCUSSIONS

The findings of the research reported that different fertilizer treatments showed non significant effect on days to seedling emergence (Table-1). The probable reason may be due to some climatic conditions which lead to the leaching of S and N from the rooting zone of the plants. But the contrasting results were observed by Ayub, *et al*., (2001) who stated that split doses of S and N application at various growth stages enhanced good plant germination. The observed results also reported a non significant association between the interaction of varieties and fertilizer treatments. Similarly both the varieties also showed non significant relationship on the concern parameter. However from the means of planned comparison of two varieties of wheat reported that S alone effect on days to seedling emergence was found significant Figure-1(A). It may be due to the fact that S is

becoming an utmost important requirement for cereals during reproductive as well as at vegetative stage. This statement is supported by McGrath, (2003); Gyori, (2005) who investigated that S deficiency significantly effects the growth and quality of wheat. From the means of planned comparison of two varieties it was also observed that soil applied S vs. soil + foliar applied S showed significant relationship on days to seedling emergence Figure-1(A). While the interaction between year and variety showed non significant observations.

Data concerning total number of tillers m^{-2} is presented in Table-1. Data reported significant affect on the application of both N and S treatments. The reason for the concern result is that split dose of both N and S application at sowing and vegetative stage or vegetative and boot stage increased number of tillers m^{-2}. These results are in conformity with the findings of Zebarth and Sheard (1992) who investigated that the application of adequate amount of N at proper timings has a greatest bearing in total number of tillers m^{-2}. Similarly the interaction between variety and different combinations of S and N treatments also showed highly significant affect. Maximum number of tillers (304) was produced by Khyber-87 when compared with Pirsabaq-2005. Maximum number of tillers was produced by control treatment. The reason may be that the soil of control plot may already richer with nutrients supplements. But the contrasting observations were produced by Iqtidar, *et al*., (2006) who reported that N improved WUE, increased shoot survival by staying green till maturity. These favorable effects of N led to the production of more tillers m^{-2}. From the analysis of planned comparison of different fertilizers treatments on two varieties revealed that no fertilizer vs. fertilizer treatment as well as recommended treatment of N vs. other treatments also presented significant affect on total number of tillers m^{-2} shown in Figure-1(B). This may be due to the fact that N is an essential element for growth and development and thus promotes tillers production. Significant effects of split application of N on total tillers have been reported by other researchers (Miceli, *et al*., 1992; Ijaz, 1994). Planned comparison of fertilizers on two varieties of wheat reported that S showed significant affect Figure-1(B). The reason may due to that S fertilization not only resulted in greater translocation of photosynthates initially but also accounted for greater number of productive tillers during reproductive stage. Results also indicated that foliar as well as soil application of S increased tillers production m^{-2}. Likewise it was also found that foliar as well as soil application of urea also showed significant results Figure-1(B). Similar results were also reported by (Otteson, *et al*., 2007 and 2008). The interaction effect between varieties and comparison between no fertilizers vs. fertilizers application also gave significant results Figure-1(B).

It is evident from the data that the application of both S and N either as soil applied or as foliar applied had a significant effect on plant height (Table-1). The highest plant height (97.6cm) was observed in treatment number-3. The probable reason could be more vegetative growth at high dose of soil applied N which could have resulted in taller plants. It may also be due to greater and more efficient absorption of N which could have resulted in taller plants. These results are in agreement with those reported by Ling and Silberbush, (2002). Both the varieties also showed highly significant effect on plant height. Maximum plant height (97cm) was found in Pirsabaq-2005 as compared with the other variety. The reason may be the genetic makeup of the concern variety to produced taller plants. The findings of the results also showed that the interaction between fertilizer treatments and varieties was also reported significant results. The reason may be attributed to high availability of N and S which improved the soil structure for better growth and development. These results are in line with those of Matsi, *et al*., (2003) who contributed that best plant height of wheat is due to more availability of macro and micro nutrients which improved the soil water holding capacity. Likewise the interaction among year, variety and fertilizers treatment also gave significant result shown in Figure-2. From the means of planned comparison of the two varieties it was also observed that the application of soil applied S vs. soil + foliar applied S also showed significant result presented in Figure-1(C). The probable reason may be that split dose of S at tillering and at anthesis stage which increased the plant height. Similar results were presented by Jarvan and Adamson, (2008) who stated that S fertilization during the growing season considerably enables an increase in plant height. From the means of planned comparison it was also concluded that the effect of soil applied urea vs. soil+ foliar applied urea also presented significant result shown in Figure-1(C). The probable justification may be that soil as well as foliar applied N increase internodes length which ultimately resulted in increased height also N application enhanced the overall vegetative growth. These results matched with those given by Bakth, *et al*., (2010) that observed foliar as well as soil application of N significantly increased growth characteristics. Mean comparison also showed that the effect of S alone treatment was also found significant Figure-1(C). It may be due to that S application at tillering stage improved dry matter production in leaves, stem and ear heads which add to lavish growth. Similar results were produced by Snehal and Vilas, (2000) that S as ammonium sulphate contributed to increase the height of sugar cane. Means of planned comparison also showed significant relationship between no fertilizers vs. fertilizer application comparison.

It is obvious from the data that there are no significant differences among the mean values of different fertilizer treatment combinations on days to flowering reported in Table-1. These results are in contrast with those of Sarkar, *et al*., (1990) who proposed that N application at different growth stages like split at sowing; tillering and flowering gave optimum grain yield. These contradictory results might have been due to differences in both N and S doses, its application timings and fertility status of the soil. Also the mean values of the two varieties reflected no significant differences. But significant effects

of split application of S and N on flowering have been reported by Jan and Khan, (2000). The variation in results may be due to varying response of varieties to N and S application or might be difference in genetic makeup of varieties. Likewise there is no significant association between the interaction of fertilizer treatments and varieties. However the interaction between year and varieties showed significant effect (Table-1). These results are in conformity with those of Hamid and Sarwar, (2000) who investigated that application of S (30 kg S/ha) and N (120 kg N/ha) on different wheat varieties at different growth stages i.e., half at the time of sowing and half further split into tillering and boot stage increased flowering. Similarly from the mean values of the planned comparison of N and S treatment combinations on two varieties of wheat showed no significant differences among different interaction comparisons Figure-1(D). This might have been due to the fact that flowering in this situation is most probably the results of plants adjustment to various climatic conditions.

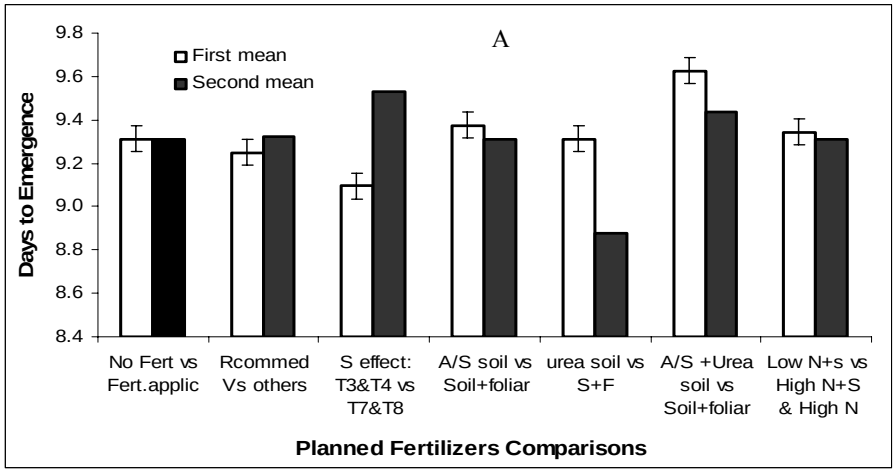
The data about days to physiological maturity is given in Table-1. Data showed that both the varieties have highly significant effect on days to physiological maturity. Khyber-87 took more days to physiological maturity (182 days) as compared with Pirsabaq-2005 which took (180 days). The data also presented that different treatment combinations of S and N showed non significant effect on days to physiological maturity. The probable reason may be that N accelerates vegetative growth which delayed maturity. Similar results were also presented by Ling and Silberbush, (2002) that reported that foliar and soil application of N enhanced growth characteristics. Likewise the interaction between fertilizer treatments and varieties was also found non significant. However the interaction effect between year and varieties was found significant. The data from the planned comparison of the two varieties influenced by different fertilizers treatment combinations showed that the comparison between recommended fertilizers vs. other fertilizer treatment showed significant effect presented in Figure-1(E). It may be due to that plants take up N from the time the roots begin to function until all uptake of nutrients ceases with maturity. However, the largest amount are taken during early stages of growth, held for later use and translocated within the plants where needed up to maturity attained. Such results are also reported by Vagen, (2003) for broccoli. Similarly the comparison between ammonium sulphate + urea soil applied vs. soil+ foliar applied also gave significant effect.

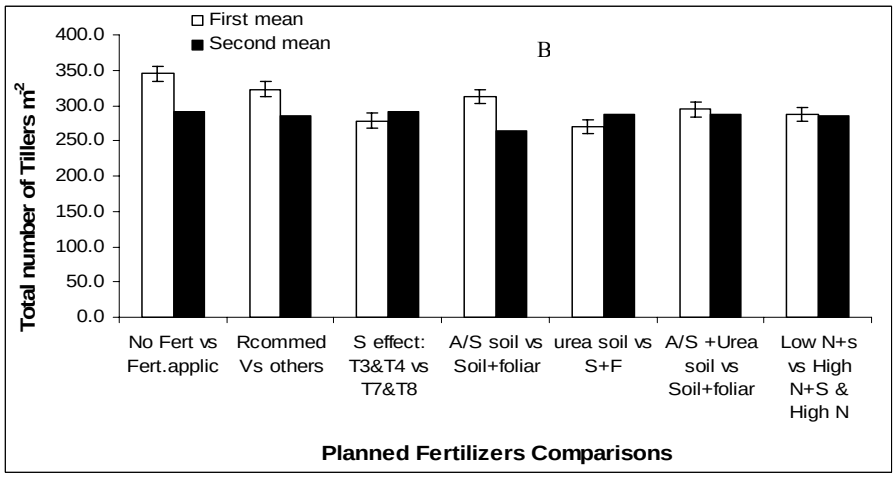
Considering straw yield the data reflected significant effect of both S and N application on two varieties of wheat. It is evident from the (Table-1) that maximum straw yield (8458 kg/ha) was produced by treatment number 8. The possible reason might be that both N and S are readily available and not retained in the soil for longer time and so translocated soon to leaves and stem yielded higher straw. These results are in agreement with those of Tila Muhammad, *et al*., (1987) who reported maximum straw yield when N and S is applied in split doses at different growth stages. While the minimum yield (5564 kg/ha) was produced by control treatment. The data from the Table-1 also reported that Pirsabaq-2005 yielded more straw yield (7106 kg/ha) as compared with the other variety. From the means of planned comparison of two varieties it was observed that the comparison of no fertilizer treatment vs. fertilizers application showed significant effect presented in Figure-1(F). The probable reason may be that fertilizers application at sowing is not necessarily optimal or sufficient for stable grain and straw yield of wheat, but precise timings of S and N application to wheat during various phases of its growth and development is an important factor. These results are in line with those of Alaston, (1979) who reported increased straw yield with foliar application of N and S at different growth stages. The findings of the planned comparison of two varieties of wheat also proposed significant association between soil applied ammonium sulphate vs. soil + foliar applied ammonium sulphate. Similarly the comparison of recommended vs. other fertilizers treatment also gave significant result shown in Figure-1(F). The greater straw yield may be due to the granular form of urea fertilizer which remained in the soil and plants get chance to uptake uniformly with moisture. These results are in conformity with those of Chajro, (1989) who reported maximum N in straw over split doses of urea. Means of planned comparison also reported that the effect of S alone on straw yield also showed highly significant result Figure-1(F). Similar results were proposed by Tiwari, *et al*., (2003) that application of 40 kg S/ha gave significantly higher yields of grain and straw in rice, wheat and sorghum. While the interaction between treatment combinations and varieties showed non significant result.

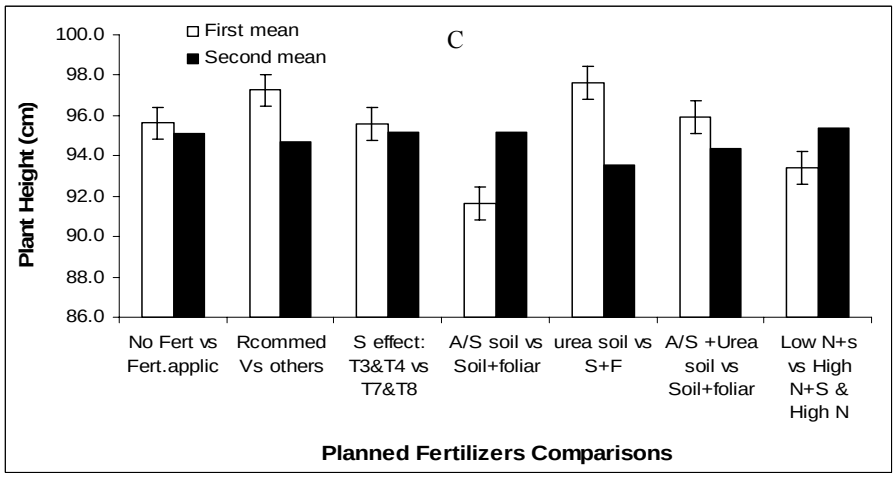
Table - 1. Effect of various N and S fertilizer treatment combinations on straw yield and growth of two varieties of wheat.

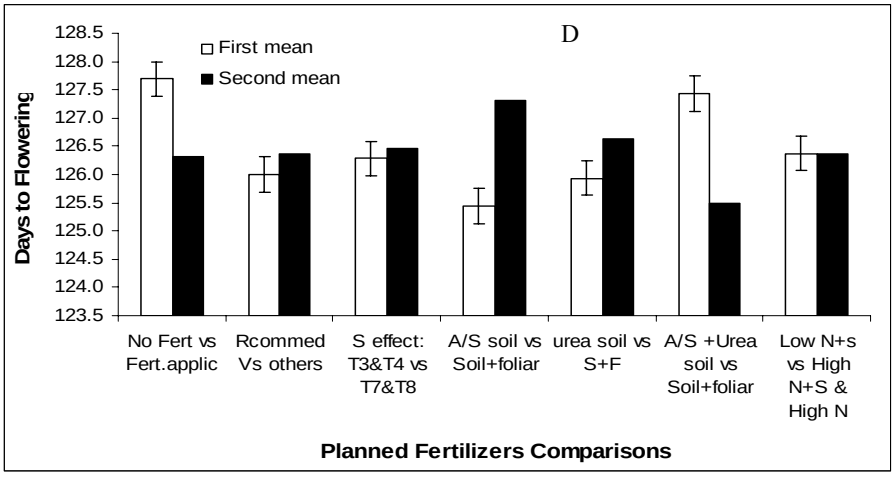
Fertilizer treatments	Days to seedling emg.			Total no. of tillers			Plant height			Days to flowering			Days to physiological maturity			Straw yield		
	Varieties			Varieties			Varieties			Varieties			Varieties			Varieties		
	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean
Control treatment (T1)	9.5	9.1	9.3	371a	319bc	345a	99.9a	91.3de	95.6ab	127.9	127.5	127.7	179.5	182	180.9	5594	5534	5564e
Recommended dose (T2)	9.1	9.4	9.3	311bc	334abc	323ab	97.4ab	97abc	97.2a	126.9	125.1	126	180.6	182	181.3	5870	5647	5759e
Soil applied N (T3)	9.0	9.6	9.3	237de	302c	269d	99.9a	95bcd	97.6a	127.6	124.2	125.9	181.7	182.6	182.1	6613	6422	6517d
Soil and foliar applied N (T4)	8.6	9.1	8.9	235de	340abc	288cd	90ef	97abc	93bc	127.2	126	126.6	180.9	181.5	181.1	6825	6702	6764d
Soil applied S (T5)	9.5	9.3	9.4	378a	246d	312bc	97.6ab	85f	91.6c	125	125.7	125.4	181.4	182.5	181.9	7542	7432	7488c
Soil and foliar applied S (T6)	9.5	9.1	9.3	325bc	202e	263d	98ab	92cde	95abc	128.5	126.1	127.3	181.1	182.5	181.8	7858	7698	7778bc
Combination of T3 and T5 (T7)	9.8	9.5	9.6	241de	348ab	294bcd	100a	91de	96ab	128.7	126.1	127.4	181.6	182.4	182	8149	8042	8096ab
Combination of T4 and T6 (T8)	9.8	9.1	9.4	240de	336abc	288cd	90.9de	98ab	94abc	125.7	125.2	125.5	180.8	182.1	181.4	8394	8522	8458a
Mean	9.3	9.3	-	293	303	-	96.86	93.4	-	127.2	125.7	-	180.9	182.2	-	7105	7000	-
2008-09	9.6	9.6	9.6	293	303	297	99.9a	91.9c	95.9	126.8a	123.6b	125.2	187.1a	187.4a	187.2	7091	6981	7036
2009-10	9.6	9.3	9.3	293	305	299	93.9bc	94.9b	94.3	127.6a	127.9a	127.6	174.8c	177b	175.9	7120	7019	7069
LSD																		
Fertilizer treatments	-				31.08			3.561			-			-			439.45	
V x F	-				43.95			5.036			-			-			-	
Y x V	-				-			2.520			1.538			0.9682			-	
Interactions	P-value				P-value			P-value			P-value			P-value			P-value	
Y x F	0.4979				0.9825			0.0181			0.7150			0.9007			0.2065	
Y x V x F	0.4979				0.8853			0.0000			0.3261			0.4599			0.9973	

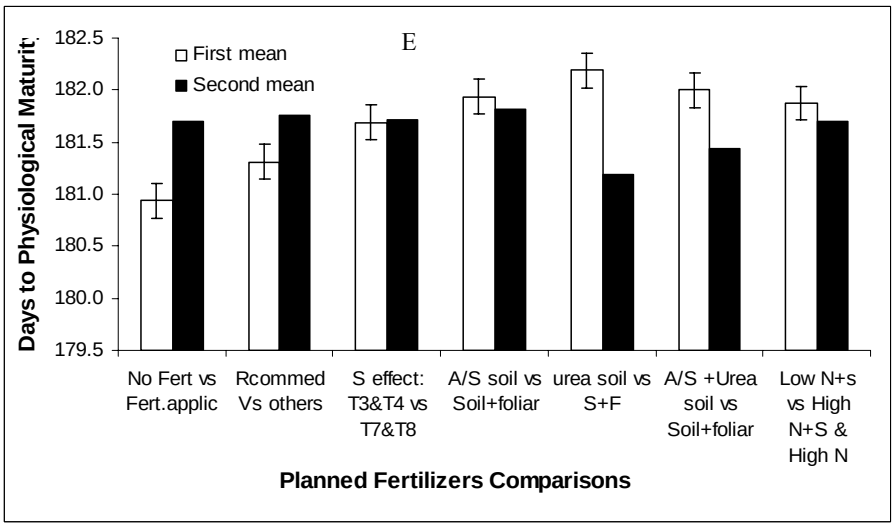
Mean of the same category followed by different letters are significantly different ($P \geq 0.05$) using LSD test.
V1 = Pir Sabaq-2005
V2 = Khyber-87
Y = Year
F = Fertilizer Treatments
V= Variety
LSD = Least Significant Difference











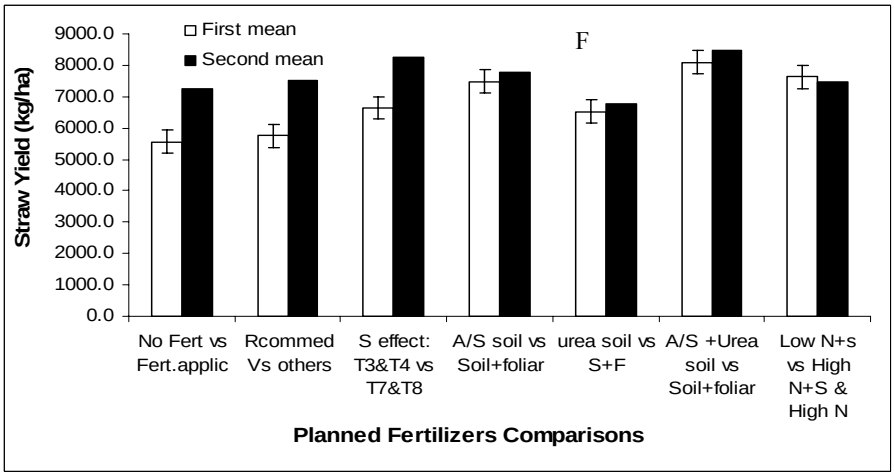


Figure-1. Planned comparison of the days to seedling emergence (A), total number of tiller m^{-2} (B), plant height (C), days to flowering (D), days to physiological maturity (E), straw yield (F) of wheat as affected by of S and N application methods.

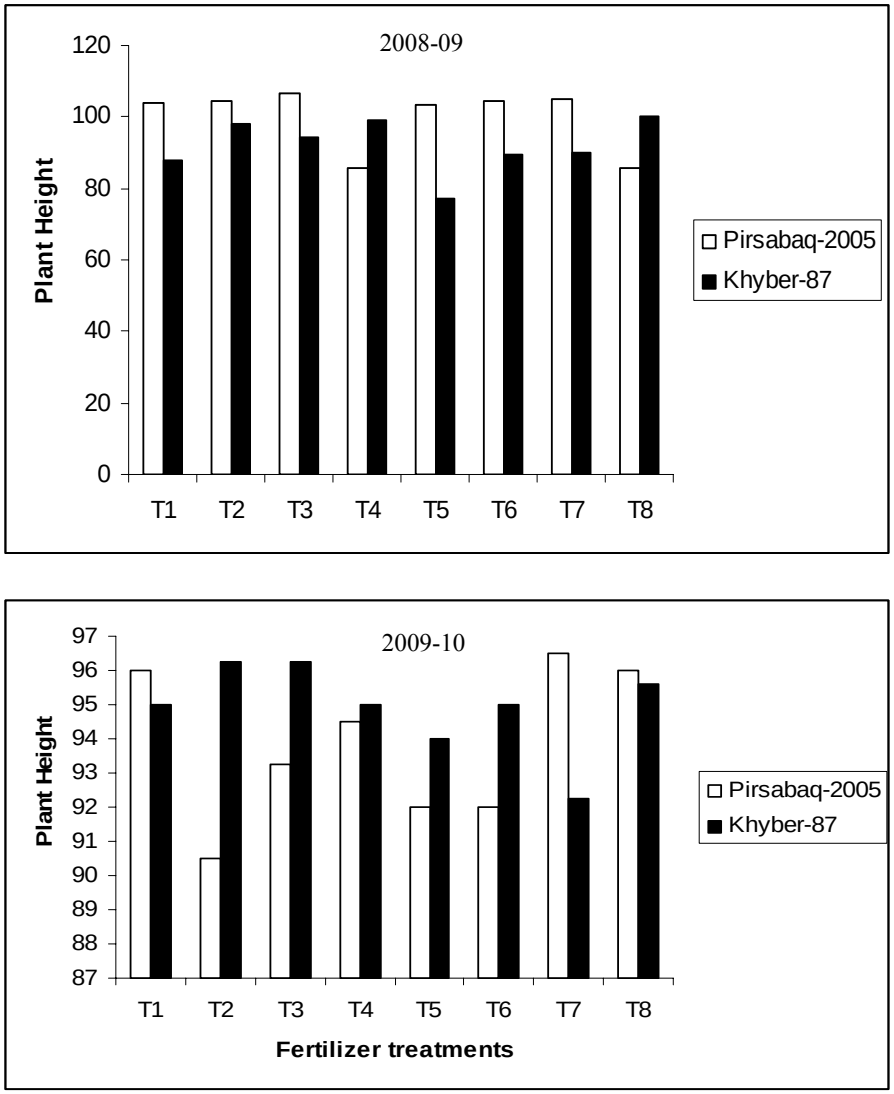


Figure-2. Plant height (cm) of two varieties of wheat showing the interaction among YxVxF as effected by rates and methods of fertilizers application during 2008-09 and 2009-10.

CONCLUSIONS

- The current study revealed a significant response straw yield to N and S combinations.
- Soil and foliar applied N and S enhanced growth factors of wheat cultivars.
- Both the varieties showed appreciable response towards N and S application over growth factors.

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