VOL. 10, NO. 4, APRIL 2015 ISSN 1990-6145
ARPN Journal of Agricultural and Biological Science

www.arpnjournals.com

EFFECTS OF NITROGEN AND FOLIAR SULPHUR APPLICATIONS ON THE GROWTH AND YIELD OF TWO WHEAT VARIETIES GROWN IN NORTHERN PAKISTAN

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ABSTRACT

A research trial was conducted at the New Developmental Research Farm of the University of Agriculture, Peshawar, Pakistan, during 2008-2009. Two wheat varieties were sown on 1st December 2008 at the seed rate of 100 kg ha^{-1}. Urea, DAP and elemental sulphur were used as sources for Nitrogen (N), Phosphorus (P) and Sulphur (S), respectively. Treatments were: Factor-A: Varieties (V), i.e., V_1 = Pirsabak-2005, V_2 = Ghaznavi-98, Factor-B: N and S application (kg ha^{-1}), i.e., T_1 (80 kg N at sowing), T_2 (140 kg N at sowing, T_3 (80 kg N at sowing and anthesis: 40+40 kg), T_4 (140 kg N at sowing and anthesis:100+40 kg), T_5 (80 kg N at sowing + 20 kg S at stem extension:), T_6 (140 kg N at sowing + 20 kg S at stem extension), T_7 (80 kg N at sowing + 20 kg S at anthesis), T_8 (140 kg N at sowing + 20 kg S at anthesis). The experiment was set in randomized complete block design (RCBD). Applications of 140 kg N ha^{-1} at sowing alongside applications of 20 kg S ha^{-1} at anthesis was helpful in increasing grain yields in both varieties. It was therefore recommended that foliar S should be included as an important input, alongside N, in the production technology of both Pirsabak-2005 and Ghaznavi-98 varieties of the wheat crop which are being cultivated in the Peshawar region of Pakistan.

Keywords: foliar sulphur, nitrogen, wheat, grain yield, biological yield.

INTRODUCTION

Wheat (*Triticum aestivum* L.) yield and productivity can be increased by manipulating the components of yield (Malik, 2007). It was observed by Akhtar (2001) that germination was not affected significantly by N levels, while plant height, number of tillers, number of fertile tillers, spike length, number of spikelet spike^{-1}, grains spike^{-1}, 1000-grain weight, biological yield, grain and straw yield and harvest index were significantly affected by N levels. When N and S fertilizers were applied simultaneously (Tea *et al*. 2007), N and S recoveries were 68% and 12%, respectively. A synergistic effect between the foliar applied N and S fertilizers appeared to increase N and S assimilation in grain which may improve bread-making qualities. Griffiths *et al.* (1995) applied elemental S (32 kg S ha^{-1}) and urea (30 kg N ha^{-1}) to the foliage of different winter wheat cultivars, half at flag leaf emergence and half at ear emergence, in factorial experiments in 1986, 1987 and 1988. Leaf senescence at the end of grain growth was delayed by S in two of the three years, both with and without urea in 1987, but only with urea in 1988. S, both alone and mixed with urea, increased grain S concentration from early grain growth in 1986 and 1987, but not until the end of grain growth in 1988. Urea alone reduced yield in 1986 and 1987, but mixing S with the urea compensated for this phytotoxic effect. Yield was not significantly increased by S when compared with plots receiving neither urea nor S. Michael (1997) conducted nine experiments on three different soil types in the south-east of Ireland over a three-year period to examine the effect of six commercially-available N fertilizers (some containing S) and foliar-applied S on the grain yield and quality of spring-sown malting barley. Most of the applied N fertilizers at the rate of 100 kg ha^{-1} gave similar yields and grain N levels. Urea, even when worked into the soil at sowing time, gave significant yield reductions in six of the experiments when compared with the other five N sources. The urea-treated plots gave significantly lower grain N levels in only one of the experiments. The S-containing N fertilizers gave significantly greater yields than the non-S-containing calcium ammonium sulphate in two of the three experiments on the light-textured sandy soil only, but had no effect on grain N or grain size. Foliar-applied S had little effect on grain yield or quality. Kimura *et al.* (2001) investigated the effect of a top-dressing of N fertilizer after anthesis on N accumulation and protein composition in wheat grain. Wheat protein content and grain weight were increased by N top-dressing after anthesis without changing stem length, ear length or yield. The accumulation of N in grain was approximately 70% of the absorbed N in a plant. On the contrary, 90% of N top-dressed after anthesis accumulated in grain. There was little difference in top-dressing N absorption in plant between 18 days after fertilization and harvest time. Hussain and Leitch (2005) conducted two field experiments to test the effects of soil- and foliar-applied S in spring wheat. S was applied at 0, 20, 40, 60 kg ha^{-1} in

1998 and at 60 kg ha^{-1} in 1999, using $CaSO_4$ as a source for the soil application and micronised S (Thiovit, 80%), with and without an organosilicone adjuvant, as a source for the foliar application. Senescence was retarded and grain yield was increased in 1998, following application of foliar S in conjunction with the organosilicone adjuvant. In 1999, grain yield was unaffected by treatments. Siaudinis and Lazauskas (2005) carried out field experiments in Lithuania (2003 and 2004). Both years, N fertilization had a significant effect on tiller formation. At harvest, the total number of tillers was approximately 0.5 tillers higher in the plots with the application of N at 120 kg S ha^{-1}. The impact of S fertilization on the number of tillers and final grain yield was not significant; nevertheless S fertilization increased the concentration of S in the aboveground plant mass. Ali (2006) conducted a field experiment during 2004-05 to study the effect of time of N application on the growth, yield and yield components of two wheat cultivars. The results showed that the time of N application significantly affected plant height number of tillers per plant, number of leaves per plant, leaf area index, flag leaf area, and shoot/root ratio. Similarly, the number of spikes per plant, number of spikelets per spike, number of seeds per spike, 1000 seeds weight, grain yield per plant, total grain yield, straw yield, and harvest index were significantly affected by time of N application. In this regard, application of N either as full dose at sowing or split into equal halves at sowing and at flowering resulted in better wheat growth and yield. Early application of N was found to be crucial for wheat growth and yield.

The current wheat yield in Pakistan is far lower than the potential yield. Hence, there is considerable scope for manipulating the components of yield through better production technology including adequate fertilizer application. This extensive research trial was designed to investigate the effects of soil applied N and foliar applied S on the growth and yield of two wheat varieties generally grown in Khyber Pakhtunkhwa - the northern province of Pakistan.

MATERIALS AND METHODS

A research trial under field conditions was conducted at the New Developmental Research Farm of the Khyber Pakhtunkhwa Agricultural University, Peshawar, Pakistan, during 2008-2009. The experimental farm is located at 34.018N latitude, 71.358E longitude at an altitude of 350 m above sea level in Peshawar valley. Peshawar is located about 1600 km north of the Indian Ocean and has a continental type of climate. Soil is clay loam, low in organic matter (0.87%), phosphorus (6.57 mg kg^{-1}), potassium (121 mg kg^{-1}) and alkaline (pH 8.2) and is calcareous in nature (Amanullah *et al.,* 2009). Mean annual rainfall ranges from 250 to 400 mm during the experimental period (Amanullah *et al.* 2008). The experiment was sown at 1st December 2008 employing seed rate of 100 kg ha^{-1}. Urea, DAP and elemental S were used as sources for Nitrogen (N), Phosphorus (P) and Sulphur (S), respectively. The experiment was irrigated five times during the growing season and weeding operation was conducted three times whilst no herbicides or pesticides were applied. Elemental S (20 kg ha^{-1}) was applied as an emulsion in the water, which was thoroughly stirred each time it was administered to the crop. Treatments employed were: Factor-A: Varieties (V), i.e., V_1 = Pirsabak-2005, V_2 = Ghaznavi-98, Factor-B: N and S application (kg ha^{-1}), i.e., T_1 (80 kg N at sowing), T_2 (140 kg N at sowing, T_3 (80 kg N at sowing and anthesis: 40+40 kg), T_4 (140 kg N at sowing and anthesis:100+40 kg), T_5 (80 kg N at sowing + 20 kg S at stem extension:), T_6 (140 kg N at sowing + 20 kg S at stem extension), T_7 (80 kg N at sowing + 20 kg S at anthesis), T_8 (140 kg N at sowing + 20 kg S at anthesis). The experiment was conducted in randomized complete block design (RCBD) with split plot arrangements having four replications. Varieties were allotted to main plots while N and S treatments were allotted to subplots (dimensions: 4 x 1.8 m having six rows, 30 cm apart and 4 m long). Data were recorded on the following parameters: (1) Leaf area: Leaf length and width of all green leaves in the five tillers were measured and leaf areas were calculated using the formula: Leaf area = Leaf Length x Leaf width x Factor 0.75. The total leaf area was then divided by the number of green leaves to obtain average leaf area of an individual leaf. (2) Days to maturity: days from planting to 75% physiological maturity - complete loss of green color from the plant was used as criterion for physiological maturity. (3) Number of spikes m^{-2}: productive spikes were counted in central two rows and converted into spikes m^{-2} using the formula: Spike m^{-2} = number of spikes of central two rows/ Row length (4 m) x number of rows i.e., 2 x Row width (0.3 m). (4) Number of grains $spike^{-1}$ and (5) 1000 grain weight: the number of grains of ten randomly selected spikes from two central rows was counted in each subplot and average grains $spike^{-1}$ were calculated. Also, weight of randomly taken 1000 grains was recorded. (6) Biological yield: two central rows of each subplot were harvested, sun dried and weighed. The yield was converted into kg ha^{-1} using the following formula: Biological yield =Biological yield of two central rows x 10,000/ Number of rows harvested i.e., 2 x row to row distance (0.3m) x row length (4m)), (7) Grain yield: two central rows in each subplot were harvested, sun dried, threshed, weighed and converted into grain yield ha^{-1} according to the following formula: Grain yield = Grain yield of two rows x 10,000/ Number of rows harvested (i.e., 2) x row to row distance (0.3m) x row length (4m).

Data were statistically analyzed using analysis of variance appropriate for randomized complete block design with split plot arrangement. Means were compared using LSD test at 0.05 level of probability, when the F-test was significant (Steel and Toorie, 1980).

RESULTS AND DISCUSSIONS

Days to maturity and leaf area (cm^2)

Maximum days to maturity were recorded in plots receiving 140 kg N ha^{-1} i.e., 100 kg N ha^{-1} at sowing and 40 kg N ha^{-1} at anthesis (Table-1). Here Pirsabak-2005 showed delayed maturity compared to Ghaznavi-98. A split application of 140 kg N ha^{-1} i.e., 100 kg N ha^{-1} at sowing and 40 kg N ha^{-1} at anthesis was more effective at delaying maturity than either 140 kg N ha^{-1} at sowing applied alone or combined with 20 kg ha^{-1} foliar applied S at stem extension or anthesis. Foliar S did not appear to have shown an influence in delaying maturity in both varieties. Applications of higher doses of N to crops have been previously observed to have enhanced vegetative growth, thus increasing days to maturity (Hussain and Leitch 2007). Foliar S at stem extension either with 140 or 80 kg N ha^{-1} caused significantly greater leaf area in Pirsabak-2005 than in Ghaznavi-98 (Table-2). Foliar S at stem extension has been reported to have an increasing effect on leaf area in wheat by several studies. It was found by Ali (2006) that leaf area increased with increased rates of N applications. In another study foliar S application of 12.5 kg S ha^{-1} at tillering increased the number of leaves, green leaf area and yield in barley (Ramos *et al.,* 1989).

1000 grain weight, number of grains spike^{-1} and spikes m^{-2}

Applications of 140 or 80 kg N ha^{-1} at sowing alongside applications of 20 kg S ha^{-1} at anthesis resulted into higher 1000 grain weight in Pirsabak-2005 compared to other treatments applied to this variety or, for same or different treatments applied to Ghaznavi-98 (Table-3). Apparently foliar applications of S at anthesis, alongside applications of N at sowing, showed better performance in terms of increasing 1000 grain weight compared to earlier applications of foliar S at stem extension. It was observed by Akhtar (2001) that germination was not affected significantly by N levels, while 1000 grain weight, biological yield and grain yield were significantly enhanced when N was applied. Application of 140 or 80 kg N ha^{-1} at sowing alone or in split application (at sowing or anthesis) with or without the application of 20 kg ha^{-1} foliar S at anthesis caused a higher number of grains $spike^{-1}$ (Table-4) Here Ghaznavi-98 produced a higher grain number $spike^{-1}$ than that of Pirsabak-2005 (Table-3). It was observed by Akhtar (2001) that the number of grains $spike^{-1}$ and fertile tillers were significantly increased with N application. In our study, foliar S application appeared to be of no influence in altering grain number significantly. Also, spikes m^{-2} remained unaffected with the application of treatments (data not shown). This was consistent with the results obtained by Hussain and Leitch (2007, 2008), where applications of S at tillering did not increase the number of grains or spikes m^{-2}. The results were, however, in contrast to other findings (Garcia Del Morel and Ramos, 1987) where a higher number of barley ears were obtained following foliar applications of S. This could be because of the difference in crop species. Foliar S application in the wheat crop may not be as effective, in increasing the number of fertile tillers at maturity, as in barley.

Biological yield and grain yield (kg ha^{-1})

Applications of 140 or 80 kg N ha^{-1} at sowing alongside applications of 20 kg S ha^{-1} at anthesis or stem extension resulted into higher biological yield compared to other treatments (Table-5). Other researchers obtained similar results. Siaudinis and Lazauskas (2005) reported that higher doses of N applications increased biological yield in wheat and altered vegetative growth characteristics. Applications of 140 kg N ha^{-1} at sowing alongside applications of 20 kg foliar S ha^{-1} at anthesis augmented grain yields in both varieties compared to other treatments (Table-6). Here, a higher grain yield was apparently recorded in Pirsabak-2005 than Ghaznavi-98. The seemingly increased grain yield in Pirsabak-2005 compared to Ghaznavi-98 appears to be the result of a higher leaf area and 1000 grain weight in this variety. In another study foliar S application of 12.5 kg S ha^{-1} at tillering increased the number of leaves, green leaf area and yield in barley (Ramos *et al.,* 1989). This was stated to be the possible hormonal effect of S absorbed by the foliage, which triggered the production of a higher number of tillers and leaves, a higher green leaf area and its subsequent decline. Insufficient S, especially when large amounts of N are being given to the plant, resulted in a decreased grain yield and a diminished S amino acid content of the grain protein as observed Roberts and Koehler (1965). One of the reasons of the favourable effects of N and S, in our study, in terms of both biological and grain yields appear to be the result of higher uptake and utilization of N when S was also applied to the crop. Nitrogen may be lost to the environment when S in the soil is not present in adequate quantity. It has been previously reported that on average, each kilogram of S missing from the plant's demands means that 15 kg of N is likely to be lost to the atmosphere (Schnug and Haneklaus, 1994) - which has economic cum environmental ramifications.

CONCLUSIONS

We conclude from this investigation that applications of 140 kg N ha^{-1} at sowing alongside applications of 20 kg S ha^{-1} at anthesis was helpful in increasing grain yields in both varieties. Here, a higher grain yield was apparently recorded in Pirsabak-2005 than Ghaznavi-98. The seemingly increased grain yield in Pirsabak-2005 compared to Ghaznavi-98 appears to be the result of a higher leaf area and 1000 grain weight in Pirsabak-2005. One of the reasons of the favourable effects of N and S, in our study, in terms of both biological and grain yields appear to be the result of higher uptake and utilization of N when S was also applied to the crop. It is recommended that foliar S should be included as an important input in the production technology of both Pirsabak-2005 and Ghaznavi-98 varieties of the wheat crop which are being cultivated in the Peshawar region of Pakistan.

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Table-1. Days to maturity of wheat varieties as affected by N and foliar S applications.

Treatments	Varieties		Mean
	Pirsabak-2005	Ghaznavi-98	
T1	155.0 e	151.7 f	153.3 c
T2	158.0 b	155.7 e	156.8 b
T3	155.0 e	152.5 f	156.7 c
T4	163.2 a	157.5 bcd	160.3 a
T5	155.0 e	151.5 f	153.2 c
T6	155.2 e	156.2 cde	155.7 b
T7	155.5 e	152.2 f	153.8 c
T8	157.7 bc	156.0 de	156.8 b
Mean	156.8 a	154.1 b	-

LSD value for varieties at $P \leq 0.05 = 0.57$
LSD value for N and S at $P \leq 0.05 = 1.20$
LSD value for interaction at $P \leq 0.05 = 1.70$

T1 = 80 kg N ha^{-1} at sowing
T2 = 140 kg N ha^{-1} at sowing
T3 = 80 kg N ha^{-1} at sowing and anthesis (40, 40)
T4 = 140 kg N ha^{-1} at sowing and anthesis (100, 40)
T5 = 80 kg N ha^{-1} at sowing + 20 kg S ha^{-1} at stem extension
T6 = 140 kg N ha^{-1} at sowing + 20 kg S ha^{-1} at stem extension)
T7 = 80 kg N ha^{-1} at sowing + 20 kg S ha^{-1} at anthesis
T8 = 140 kg N ha^{-1} at sowing + 20 kg S ha^{-1} at anthesis)

Table-2. Average leaf area (cm^2) of wheat varieties as affected by N and foliar S applications.

Treatments	Varieties		Mean
	Pirsabak 2005	Ghaznavi-98-98	
T1	29.7 ef	25.8 g	27.8 e
T2	31.3 de	28.5 f	29.9 d
T3	36.7 b	29.7 ef	35.2 b
T4	35.4 cd	30.2 ef	31.8 bc
T5	40.7 a	34.4 bc	37.6 a
T6	40.2 a	34.3 c	37.3 a
T7	34.5 bc	31.0 e	23.8 bc
T8	34.7 bc	28.0 fg	31.4 cd
Mean	35.2 a	30.3 b	-

LSD value for varieties at $P \leq 0.05 = 3.34$
LSD value for N and S at $P \leq 0.05 = 1.61$
LSD value for interaction at $P \leq 0.05 = 2.28$

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Table-3. 1000 grain weight (g) of wheat varieties as affected by N and foliar S applications.

Treatments	Varieties		Mean
	Pirsabak-2005	Ghaznavi-98	
T1	35.4 bcdef	33.9 ef	34.7 c
T2	37.8 bc	32.6 f	35.2 c
T3	37.5 bcdef	35.4 bcdef	35.4 c
T4	36.4 bcde	34.3 def	35.4 c
T5	36.0 bcde	37.4 bcd	36.7 c
T6	38.7 b	34.4 def	36.5 c
T7	44.2 a	34.9 cdef	39.5 b
T8	43.8 a	43.6 a	43.7 a
Mean	38.5 a	35.8 b	-

LSD value for varieties at $P \leq 0.05 = 0.71$
LSD value for N and S at $P \leq 0.05 = 2.42$
LSD value for interaction at $P \leq 0.05 = 3.42$

Table-4. Grains spike^{-1} of wheat varieties as affected by N and foliar S applications.

Treatments	Wheat varieties		Mean
	Pirsabak-2005	Ghaznavi-98	
T1	44.7	46.6	45.6 d
T2	53.2	54.8	54.0 abc
T3	52.5	54.9	53.7 abc
T4	51.8	53.4	52.6 bc
T5	50.4	52.8	51.6 c
T6	51.2	54.6	52.9 bc
T7	51.7	58.6	55.1 ab
T8	55.7	57.2	56.4 a
Mean	51.4 b	54.1 a	-

LSD value for varieties at $P \leq 0.05 = 0.99$
LSD value for N and S at $P \leq 0.05 = 2.80$
LSD value for interaction at $P \leq 0.05 =$ NS

Means in row or column followed by same letters are not significantly different at $P \leq 0.05$ using LSD test.

Table-5. Biological yield (kg ha^{-1}) of wheat varieties as affected by N and foliar S applications.

Treatments	Varieties		Mean
	Pirsabak-2005	Ghaznavi-98	
T1	11354.1 f	8645.8 g	10000.0 d
T2	12916.6 cdef	12500.0 def	12708.3 bc
T3	12395.8 def	12187.5 ef	12291.6 c
T4	11875.2 ef	12708.3 cdef	12291.6 c
T5	14583.3 abc	12395.8 def	13489.5 abc
T6	13541.6 bcde	15625.0 a	14583.3 a
T7	14583.3 abc	13333.3 bcdef	13958.3 ab
T8	15208.3 ab	14270.8 abcd	14739.5 a
Mean	13307.2	12708.3	-

LSD value for varieties at $P \leq 0.05$ = NS
LSD value for N and S at $P \leq 0.05$ = 1460
LSD value for interaction at $P \leq 0.05$ = 2065

Table-6. Grain yield (kg ha^{-1}) of wheat varieties as affected by N and foliar S applications.

Treatments	Varieties		Mean
	Pirsabak-2005	Ghaznavi-98	
T1	2072.9	2239.5	2156.2 d
T2	3145.8	3212.5	3179.1 bc
T3	3260.4	3000.0	3130.2 c
T4	3052.0	3346.8	3199.4 bc
T5	3197.9	3000.0	3098.9 c
T6	3385.4	3489.5	3437.4 bc
T7	3666.6	3780.3	3687.5 b
T8	4510.4	4416.6	4463.5 a
Mean	3286.4	3301.6	-

LSD value for varieties at $P \leq 0.05$ = NS
LSD value for N and S at $P \leq 0.05$ = 537.0
LSD value for interaction at $P \leq 0.05$ = NS: Means in row or column followed by same letters are not significantly different at $P \leq 0.05$ using LSD test.

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