INTERNATIONAL JOURNAL OF AGRICULTURE & BIOLOGY
1560–8530/2006/08–4–477–481
http://www.fspublishers.org

Growth, Yield and Nutrient Uptake of Wheat (*Triticum aestivum* L.) in relation to Foliar and Soil Application of Urea

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ABSTRACT

We conducted a field experiment to investigate the effect of soil and foliar spray of urea on the growth, yield, nutrient uptake and grain protein content of wheat (*cv*. 'Mehran-89'). The thrice replicated treatments included T1: 150 kg N ha^{-1} as urea by broadcasting, T2: ½ T1 + 1% foliar spray of urea (FSU), T3: ½ T1 + 2% FSU, T4: ½ T1 + 2.5% FSU. All the treatments also received a recommended blanket dose of P (75 kg ha^{-1}) and K (50 kg ha^{-1}), through soil mixing of DAP and SOP before wheat sowing. The soil application of 75 kg N ha^{-1}, in all the treatments, was done through broadcasting at the time of first irrigation. In T1, the remaining 75 kg N ha^{-1} was applied at the time of ear head emergence (EHE). The foliar application of urea was done at tillering (TL) and EHE. The experimental soil was heavy, non-saline, alkaline, and low in organic matter and P, with adequate K. The results revealed that the plant height at both EHE and maturity, number of tillers (NT) at EHE, dry weight (DW) at TL, ear head length (EHL), seed index (SI), straw yield (STY) and harvest index (HI) were remained non-significant ($p > 0.05$). Nonetheless, except for HI, T3 and T4 remained superior ($p < 0.05$) over both T1 and T2. Whereas, T3 significantly increased ($p < 0.05$) NT at maturity and grain and biological yield. The maximum significant ($p < 0.05$) DW was found at T4. The N concentration was significantly superior ($p < 0.05$) in case of T3 at TL, EHE and in straw, while in case of T4 for grain. The protein content of grain was also superior ($p < 0.05$) in case of T4. The P and K concentration were remained non-significant ($p > 0.05$) among all the treatments. The N uptake was significantly superior ($p < 0.05$) at EHE and in straw in case of T3 and in grain in case of T4. However, at TL all the treatments behaved alike ($p > 0.05$) for N uptake. The P uptake was non-significant ($p > 0.05$) at TL, EHE and in straw among all the treatments and in case of grain T3 remained significantly superior ($p < 0.05$) over all the treatments. The K uptake at TL was statistically similar ($p < 0.05$) in all the treatments, however, at EHE, and in straw and grain T3 remained significantly superior ($p < 0.05$) over all the treatments. The value cost ratio (VCR) of foliar fertilization treatments was more than that of soil application treatments. The VCR was almost similar in case of T3 and T4; however, both these treatments gave high VCR over T1 and T2. We conclude that foliar fertilization of N through 2-2.5% urea solution improved growth, yield, nutrient uptake and quality of wheat, besides offering maximum VCR.

Key words: Foliar urea; Wheat (*Triticum aestivum* L.); Grain and straw yield; NPK uptake; Value cost ratio

INTRODUCTION

The average yield of wheat (*Triticium aestivum* L.) in Pakistan (2373 kg ha^{-1}) is low as compared to world average (2714 kg ha^{-1}), or even to its neighbouring countries like India (2742 kg ha^{-1}), and China (3860 kg ha^{-1}) (MINFAL, 2005; Khan *et al.*, 2006). There is a cascade of reasons for low wheat yields in Pakistan, amongst the low fertilizer use efficiency stands on top. Jarwar *et al.* (2005) reported that the N recovery was 35.7% in case of urea and only 30% in case of ammonium nitrate, applied to wheat. The use efficiency of applied nitrogen is greatly affected by method of fertilization and a poor method can account for 20-50% yield reduction (Nisar & Rashid, 2003). The integrated soil and foliar application of fertilizer N through urea has been reported as an effective and economical application method (Khaskhely, 1991; Abdi *et al.*, 2002; Masauskas & Masaukiene, 2002; Mahajan *et al.*, 2004). It results in increased yield and yield components, improved quality attributes and cost effective production (Grewel & Mittal, 1982; Kadry *et al.*, 1984; Memon, *et al*., 1987; Shah & Saeed, 1989; Khaskhely, 1991; Czuba, 1994; Jakhro *et al.*, 2000; Emam & Borijan, 2000; Siuliauskas *et al.*, 2001). Moreover, it also increases NP uptake (Khaskhely, 1991). Greater N use efficiency (up to 160%) through foliar over soil application of urea has also been reported (Czuba, 1994). With respect to the dose of nitrogen, Jakhro *et al.* (2000) found that 1.5% foliar spray was most effective for quantitative and qualitative traits. Regarding

the most suitable stage, foliar application of urea at the end of tillering increased ear number m^{-2}, dry matter yield, grain yield, harvest index and total N uptake. Spraying at anthesis or later increases grain and plant N content at maturity Maximum grain yield is also obtained with the application of N at sowing plus a foliar application at the end of tillering (Sarandon & Gianibelli, 1990). Late foliar application could decrease nitrogen use efficiency (Emam & Borijan, 2000). It is also reported that the foliar application of urea, applied at and after anthesis, is beneficial over soil treatments in increasing grain protein content and bread making quality of wheat (Zhigulev, 1991). Moreover, Siuliauskas *et al*. (2001) found that 30 kg N ha^{-1}, applied as foliar spray during heading and at the beginning of milky ripeness increased wheat yield upto 8.54 t ha^{-1} and protein content up to 15.29%. However, these benefits of foliar fertilization of urea may be cultivar specific (Shah and Saeed, 1989; Emam & Borijan, 2000). In addition to these benefits, foliar fertilization may also help reduce the denitrification, leaching and immobilization, frequently related to N fertilization to the soil system (Gooding, 2005) by improving N use efficiency to a greater extent (Czuba, 1994). We studied the effectiveness of integrated use of soil and foliar applied urea with the objectives to explore its benefits in increasing wheat productivity, quality, profitability and nutrient uptake.

MATERIALS AND METHODS

The field experiment was consisted of 12 plots, each of 48 m^2, arranged in a randomized complete block design, containing hand drilled wheat (*cv.* 'Mehran-89').

The thrice replicated treatments included T1: 150 kg N ha^{-1} supplied to soil through urea, T2: 75 kg N ha^{-1} supplied to soil through urea + 1% foliar spray of urea, T3: 75 kg N ha^{-1} supplied to soil through urea + 2% foliar spray of urea, T4: 75 kg N ha^{-1} supplied to soil through urea + 2.5% foliar spray of urea. A recommended blanket dose of phosphorus (75 kg ha^{-1}) and potassium (50 kg ha^{-1}) were also applied to all the treatments.

The soil application of 75 kg ha^{-1} urea, in all the treatments, was done through broadcasting at the time of first irrigation. In T1, a dose of 75 kg ha^{-1} urea was also applied at the time of earhead emergence (EHE). The foliar application of urea was made on two stages, i.e. tillering (TL) and EHE. The P and K were applied through soil mixing before wheat sowing.

The soil analysis (following Ryan *et al.*, 2001) revealed that the soil under study was heavy in texture (42.5% clay), alkaline in nature (pH: 8.02), non-saline (EC: 0.30 dS m^{-1}), calcareous in reaction ($CaCO_3$: 11.5%), low in organic matter content (0.69%) and $NaHCO_3$-extractable P (2.98 mg kg^{-1}), while adequate in NH_4OAc-extractable K (169.75 mg kg^{-1}).

The plant samples were taken at TL and EHE, processed and analysed for NPK determinations, following Ryan *et al.* (2001). The crude protein percent of grain was calculated by multiplying N% of grain with a factor of 5.7. The nutrient uptake was calculated on the basis of nutrient measured in plants (straw + grain) multiplied by yield in kg ha^{-1} and then divided by 100.

The agronomic observations recorded are shown in Table I. The harvest index was calculated by dividing the grain yield with biological yield (straw + grain) and by multiplying the product by 100. The value cost ratio (VCR) was the value of increased yield divided by the cost of the fertilizer spent over that increased yield.

The data recorded were subjected to analysis of variance and LSD test was employed to test the superiority of treatment mean, using MSTAT-C version 1.42.

RESULTS

Yield and yield components. The results regarding yield and yield components (Table I) are presented next.

Plant height. Foliar spray of urea had non-significant effect on plant height at EHE. However, the highest plant height (39.77 cm) was recorded where 75 kg N ha^{-1} broadcasted along with 2.5% foliar spray of urea. The lowest plant height (35.57 cm) was measured with 75 kg N ha^{-1} broadcasted along with 1.0% foliar spray of urea. Each increment in the concentration of foliar spray of urea increased plant height over soil application. Almost similar trend was obtained for the effect of foliar spray of urea in increasing plant height at maturity.

Number of tillers. A non-significant increase with foliar spray of urea over soil application was observed for the number of tillers at EHE. However, foliar spray of urea significantly increased the number of tillers (m^{-2}) at EHE over soil application. At EHE, the highest number of tillers (709.26) was obtained with the broadcasting of 75 kg N ha^{-1} along with 2.5% foliar spray of urea. It followed by the treatment where 75 kg N ha^{-1} was applied through broadcasting along with 2.0% foliar spray of urea. The lowest number of tillers (601.37) were recorded where 75 kg N ha^{-1} was broadcasted along with 1.0% foliar spray of urea, over soil application of 150 kg N ha^{-1}. When the number of productive tillers was recorded at maturity, it became apparent that the treatments were significantly different. The maximum number of productive tillers (703.92) was recorded where 75 kg N ha^{-1} was applied through broadcasting along with 2.5% foliar spray of urea. The minimum number of tillers (597.14) was recorded with the broadcasting of 75 kg N ha^{-1} along with 1.0% foliar spray of urea.

Plant dry weight. The foliar spray of urea had non-significant effect on plant dry weight at tillering stage. Maximum plant dry weight (2651 kg ha^{-1}) was recorded with soil application of 75 kg N ha^{-1} along with 2.5% foliar spray of urea. The minimum plant dry weight (2081

Table I. Yield and yield components of wheat under foliar fertilization of urea

Treatment	Plant height (cm)		No. of Tillers (m^2)		Dry weight (kg ha^{-1})		Earhead	Seed	Yield (kg ha^{-1})			Harvest
	EHE	MT	EHE	MT	TL	EHE	length (cm)	index (g)	Straw	Grain	BLG	index (%)
T1	36.93	103.97	641.17	637.01ab	2301	3030c	10.68	43.27	3760	3470b	7230c	48.21
T2	35.57	102.37	601.37	597.14b	2081	2755d	10.51	41.12	3430	3200c	6630c	48.32
T3	39.37	104.6	671.25	666.43ab	2502	3421b	11.06	44.03	4340	3940a	8280ab	47.66
T4	39.77	104.77	709.26	703.92a	2651	3581a	11.11	45.68	4510	4110a	8620a	47.68
LSD 5%	6.14 NS	6.36	76.55 NS	70.88	1409NS	90.83	1.06	4.02NS	922.3NS	229.25	1058.8	5.49NS

EHE: Earhead emergence, MT: Maturity, TL: Tillering, BLG: Biological, T1: 150 kg N ha^{-1} as urea by broadcasting, T2: ½ T1+ 1% foliar spray of urea (FSU), T3: ½ T1 + 2% FSU, T4: ½ T1 + 2.5% FSU

Table II. Nutrient concentration and grain protein content of wheat under foliar fertilization of urea

Treatment	Nitrogen concentration (%)				Phosphorus concentration (%)				Potassium concentration (%)				GPC
	TL	EHE	Straw	Grain	TL	EHE	Straw	Grain	TL	EHE	Straw	Grain	(%)
T1	0.347b	0.459b	0.327c	0.746d	0.373	0.117	0.089	0.487	5.34	2.84	2.4	0.602	4.251d
T2	0.587b	0.665b	0.377b	0.883c	0.371	0.117	0.088	0.486	5.33	2.83	2.2	0.603	5.033c
T3	0.882a	1.167a	0.390a	1.304b	0.372	0.116	0.087	0.483	5.32	2.84	2.24	0.602	7.431b
T4	1.045a	1.183a	0.394a	1.444a	0.372	0.118	0.089	0.487	5.34	2.81	2.36	0.601	8.233a
LSD 5%	0.267	0.243	0.011	0.129	0.005NS	0.03NS	0.004NS	0.009NS	1.07NS	0.42NS	0.42NS	0.097NS	0.736

TL: Tillering, EHE = Earhead emergence, GPC = Grain protein content, T1: 150 kg N ha-1 as urea by broadcasting, T2: ½ T1 + 1% foliar spray of urea (FSU), T3: ½ T1 + 2% FSU, T4: ½ T1 + 2.5% FSU

kg ha^{-1}) was recorded where 75 kg N ha^{-1} was applied through broadcasting along with 1.0% foliar spray of urea. However, the foliar spray of urea had significant effect on plant dry weight at EHE. The maximum plant dry weight (3581 kg ha^{-1}) was recorded with the soil application of 75 kg N ha^{-1} along with 2.5% foliar spray of urea. The minimum plant dry weight (2755 kg ha^{-1}) was recorded for the treatment where 75 kg N ha^{-1} was applied to soil and supplemented by 1.0% foliar spray of urea.

Ear head length. The effect of soil and foliar spray of urea remained non-significant in improving earhead length (EHL). Nonetheless, maximum EHL (11.11 cm) was recorded where 2.5% foliar spray of urea was supplemented to soil application of 75 kg N ha^{-1}, followed by (11.06 cm) the application of 75 kg N ha^{-1} through broadcasting along with 2.0% foliar spray of urea.

Seed index. The integrated application of nitrogen through soil and foliage did not show a significant effect. However, the maximum seed index (45.68 g) was obtained with the soil application 75 kg N ha^{-1} through along with 2.5% foliar spray of urea. It was followed by the maximum seed index (44.03 g) with the soil application of 75 kg N ha^{-1} alongwith 2.0% foliar spray of urea, over 150 N kg ha^{-1} soil application, or soil application of 75 kg N ha^{-1} along with 1.0% foliar spray of urea.

Wheat yield. A non-significant effect on straw yield by soil and foliar spray of urea was observed. The maximum straw yield (4510 kg ha^{-1}) was recorded with the soil application of 75 kg N ha^{-1} along with 2.5% foliar spray of urea while the minimum straw yield (3430 kg ha^{-1}) was recorded where 75 kg N ha^{-1} was broadcasted along with 1.0% foliar spray of urea respectively. However, generally there was an apparent increase in straw yield with foliar spray of urea over soil application. Unlike straw yield, the grain yield of wheat was significantly increased by the integrated application of urea through broadcasting and foliar spray over soil application alone. The maximum grain yield (4110 kg ha^{-1}) was recorded with the soil application of 75 kg N ha^{-1} soil along with 2.5% foliar spray of urea. The minimum grain yield (3200 kg ha^{-1}) was recorded by the soil application of 75 kg N ha^{-1} along with 1.0% foliar spray of urea. Almost similar effect of soil application and foliar spray of urea was observed on biological yield (straw+grain), as was observed for grain yield.

Harvest index. There was a non-significant effect of soil and folair spray of urea on harvest index (HI). The maximum HI (48.32%) was obtained with the soil application of 75 kg N ha^{-1} along with 1.0% foliar spray of urea. It followed by the HI (48.21%) recorded where 150 kg N ha^{-1} was applied to soil application. The lowest HI (47.66%) was recorded with the application of 75 kg N ha^{-1} soil along with 2.0% foliar spray of urea.

Plant Analysis

Nutrient concentration. The data (Table II) revealed that the application of urea by broadcasting at 75 kg N ha^{-1} along with 2.0% and 2.5% foliar spray of urea significantly increased N concentrations of 0.882% and 1.045% in plant over soil + 1.0% urea spray, at tillering stage. The lowest N concentration of 0.347% was determined with soil app of 150 kg N $ha^{-1.}$ Similar effect was observed on nitrogen concentration of wheat at EHE. However, the 75 kg N ha^{-1} soil + 2.5% foliar spray of urea had more N concentration at EHE over soil application as well as 1.0% urea spray. The nitrogen concentration of straw was significantly effected by the integrating foliar

Table III. Nutrient uptake of wheat under foliar fertilization of urea

Treatment	Nitrogen uptake (kg ha^{-1})				Phosphorus uptake (kg ha^{-1})				Potassium uptake (kg ha^{-1})			
	TL	EHE	Straw	Grain	TL	EHE	Straw	Grain	TL	EHE	Straw	Grain
T1	7.98	13.92b	12.29b	25.96c	8.58	3.56	3.36	16.89b	123.12	85.94bc	88.99ab	20.89bc
T2	12.19	18.31b	12.91b	28.27c	7.7	3.22	3.02	15.56c	111.71	77.92c	75.82b	19.32c
T3	22.07	39.93a	16.95a	51.37b	9.31	3.97	3.78	19.04a	132.64	97.26ab	97.07a	23.71ab
T4	27.77	42.38a	17.78a	59.36a	9.85	4.22	4.01	20.00a	143.42	100.63a	106.65a	24.65a
LSD 5%	14.59NS	9.05	3.158	6.081	5.153NS	0.822NS	0.902NS	1.222	85.97NS	11.79	20.51	3.597

TL: Tillering, EHE = Earhead emergence, T1: 150 kg N ha-1 as urea by broadcasting, T2: ½ T1 + 1% foliar spray of urea (FSU), T3: ½ T1 + 2% FSU, T4: ½ T1 + 2.5% FSU

Table IV. Effect of soil and foliar spray of urea on value cost ratio (VCR)

Treatments	Yield (kg ha^{-1})		Income (Rs)			Cost of fertilizer	Net profit	VCR
	Straw	Grains	Straw	Grains	Total	(Rs)	(Rs)	
T1	3760	3470	4700	26025	30725	7175	23550	4.28
T2	3430	3200	4287	24000	28287	6321	21966	4.47
T3	4340	3940	5425	29550	34975	6852	28123	5.10
T4	4510	4110	5637	30825	36462	7111	29351	5.13

Prices: urea: Rs. 425/50 kg, DAP: Rs. 800/50 kg, SOP: Rs. 800/50 kg, wheat grain: Rs. 300/40 kg, straw: Rs. 50/40 kg, T1: 150 kg N ha^{-1} as urea by broadcasting, T2: ½ T1 + 1% foliar spray of urea (FSU), T3: ½ T1 + 2% FSU, T4: ½ T1 + 2.5% FSU

application with soil application as compared to soil application alone. The highest value (0.394%) was observed with soil applied 75 kg N ha^{-1} along with 2.5% foliar spray of urea. It was observed from plant analysis that nitrogen concentration was decreased in straw as compared to nitrogen concentration at tillering and EHE stages. Moreover, the integration of 75 kg soil applied N ha^{-1} and 2.5% foliar spray of urea significantly increased nitrogen concentration over all the treatments. Almost similar results were observed for protein content of grain.

There was a non-significant effect of soil and foliar spray of urea on phosphorous concentration in wheat at various stages and the values did not differ too much. Alike trend was observed for potassium concentration of wheat, as a result of different treatments.

Nutrient uptake. The data (Table III) indicated that a non-significant effect of foliar spray of urea on N uptake at tillering stage. The maximum N uptake (22.77 kg ha^{-1}) was observed where 75 kg N ha^{-1} was applied to soil along with 2.5% foliar spray of urea. However, the foliar spray of urea had significant effect on nitrogen uptake by wheat at EHE. The maximum N uptake (42.38 kg ha^{-1}) was observed with the application of 75 kg N ha^{-1} soil along with 2.5 % foliar spray of urea. The minimum N uptake (13.92 kg ha^{-1}) was observed with the soil application of 150 kg N ha^{-1} alone. Significant effect of foliar spray of urea was also observed on nitrogen uptake at straw. However, the application of 75 kg N ha^{-1} through soil along with 2.5% foliar spray of urea had more N uptake over soil application as well as 1.0% urea spray, respectively. The nitrogen uptake of grains was significantly increased by 75 kg N ha^{-1} soil supplemented with foliar spray of urea, either at 2 or 2.5% solution. These both treatments were statistically non-significant.

There was a non-significant effect of soil and foliar spray of urea on phosphorous uptake of wheat at tillering. Maximum P uptake (9.85 kg ha^{-1}) was observed with the soil application of 75 kg N ha^{-1} along with 2.5% urea as foliar spray. The minimum (7.70 kg h a^{-1}) P uptake was obtained by the soil application of 75 kg N ha^{-1} soil + 1.0% foliar spray of urea. Almost similar trend in P uptake was observed at EHE and P uptake by straw. However, P uptake in grain was significantly affected.

The application of 75 kg N ha^{-1} to soil supplemented by 2 or 2.5% foliar spray of urea had more P uptake over soil application or soil application integrated with 1.0% urea spray. The highest P uptake was determined in grain as compared to other physiological stages of growth.

There was non-significant effect of soil and foliar spray of urea on potassium uptake of wheat at tillering. Maximum K uptake (143.42 kg ha^{-1}) was attained by soil application of 75 kg N ha^{-1} in conjunction with 2.5% foliar spray of urea. The minimum K uptake (111.71 kg ha^{-1}) was observed with 75 kg N ha^{-1} applied to the soil along with 1.0% foliar spray of urea. However, K uptake at EHE was significantly affected. The application of 75 kg N ha^{-1} to soil with 2.5% foliar urea yielded maximum K uptake (100.63 kg ha^{-1}). Almost similar trend was observed for the K uptake of wheat straw and grains.

Value Cost Ratio (VCR). The results (Table IV) revealed that the maximum profits of Rs. 29351, with a VCR of 5.13, and Rs. 28123, with a VCR of 5.10, were obtained by the application of 75 kg N ha^{-1} along with 2.5% and 2% foliar urea, respectively.

DISCUSSION

Foliar application of urea has been proved to be an effective technique of N fertilization. The adoption of foliar urea may help reduce the losses due to denitrification, leaching and immobilization, often associated with N fertilization to the soil system (Gooding, 2005). In our experiment, the application of urea through soil + foliar spray at 75 kg N ha^{-1} soil +

2.5% foliar spray generally increased plant height, number of tillers, plant dry weight, length of earhead, seed index , straw yield, grain yield, biological yield and harvest index. This suggests the quick absorption of nitrogen due to foliar spray of urea. The above findings are in line with the previous studies (Memon, 1987; Shah & Saeed, 1989; Sarandon & Gianibelli, 1990; Khaskhely, 1991; Zhigulev, 1991; Emam & Borijan, 2000; Jakhro *et al*., 2000; Siuliouskas *et al.*, 2001; Abdi *et al.*, 2002; Masauskas & Masauskiene, 2002; Mahajan *et al.*, 2004). These studies reported that foliar spray of nitrogen along with soil application increased growth, yield and yield components as compared to single mode of soil application. The effectiveness of foliar applied urea is reported upto 90-160% of that of soil application (Czuba, 1994). The plant nitrogen concentration in straw and grain was increased with 75 kg N ha^{-1} soil + 2.5% foliar spray of urea and this, in turn, resulted in higher grain protein content but no effect on phosphorous and potassium. This might suggest the better utilization of N from foliar spray of urea. The plant NPK uptake was also increased with 75 kg N ha^{-1} soil + 2.5% foliar spray of urea. This was possibly the quick absorption of N by plants through foliar spray. Khokhar (1985) reported that applying the urea through soil application resulted about 50% nitrogen loss due to volatilization and leaching. The results are in agreement with the findings of Khaskhely (1991), Zhigulev (1991), Siuliouskas *et al.* (2001), Abdi *et al.* (2002) and Gooding (2005). These researchers reported that foliar spray of urea/N along with soil application increased N content in straw and grain and also increased protein content in grain. In line to these results, Czuba (1994) also reported greater N use efficiency (upto 160%) of foliar applied urea as compared to soil application.

In general, our results revealed the superiority of the foliar applied urea over soil application in increasing the productivity, quality and profitability of wheat. Moreover, better nutrient content and uptake of wheat revealed the environment friendly nature of this fertilization technique.

CONCLUSION

The integrated application of 75 kg N ha^{-1} and 2-2.5% foliar urea was proved highly beneficial in increasing the growth and yield of wheat, improving protein content of grain and nutrient content and uptake of wheat. These treatments also resulted in the maximum profit with highest value cost ratio.

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(Received 19 April 2006; Accepted 01 June 2006)