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Substitution of soil application of urea with foliar application to minimize the wheat yield losses

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Abstract

Present energy crisis has increased the cost of fertilizer production and affected the supply in market. The problem becomes serious when the availability of nitrogen fertilizer especially urea is reduced during sowing season. It is reported in literature that fertilizer efficiency particularly urea application through soil is not as effective as if it is applied to plants through foliage along with soil application. Present study was planned to address this issue so that the yield losses due to non-availability of urea can be reduced by foliar application at various growth stages of wheat and economic use of nitrogen fertilizer. A field study was conducted for three consecutive years at Soil Chemistry Section, Institute of Soil Chemistry and Environmental Sciences, Ayub Agricultural Research Institute Faisalabad. Soil application of urea was compared with 1% spray of urea (6 sprays; from 2 leaves to booting stage), 2% spray of urea (at two leaves, tillering and booting stage), 3% spray of urea (at tillering and booting stage) and ½ urea as soil application + 2% spray of urea (at tillering and booting stage). Yield components, grain yield data, nitrogen concentration in grain and uptake and cost benefit ratio were calculated. Three year pooled wheat grain yield data indicated that ½ soil + 2 sprays of 2% urea significantly increased the grain yield (4.97 t ha^{-1}) and was at par with soil application of urea. Concentration and uptake of nitrogen increased in grain by foliar application of urea as compared to soil application at sowing due to efficient mobilization of nitrogen to grain after foliar fertilization. Cost benefit ratio showed that although 2 and 3% foliar application of urea gave maximum return by spending minimum, however the grain yield was significantly lower than soil applied urea at sowing and integration of soil and foliar application of urea. The integrated use of soil and foliar application of urea gave statistically similar yield to soil applied urea at the time of sowing. It is concluded from the study that foliar application of urea [(2% spray of urea (at two leaves, booting and tillering stage) or 3% spray of urea (at tillering and booting stage)] along with soil application is economical and can compensate the yield losses.

Keywords: *Nitrogen, substitution, urea, soil, foliar, wheat yield*

Introduction

The yield of a crop depends upon the interaction between its genetic potential and the environment in which it grows. Full exploitation of the genetic potential requires optimum fertilizer application. Nitrogen is an essential plant nutrient and involves in enzymatic reactions, protein synthesis and is a major component of amino and nucleic acids but it is the most deficient nutrient (94%) in Pakistani soils (FAO, 2004).Therefore, adequate supply is necessary to obtain maximum yield potential of crops (Mae, 1997; Akram *et al*., 2010). Wheat is important cereal food crop in Pakistan. It is effectively cultivated on more than 9 million hectares with a production of 24 million tons. The wheat demand is gradually increasing every year due to population pressure but its yield per hectare is low. There are various reasons for low yield in Pakistan. Among these reasons timely availability of nitrogenous fertilizer is very important. Wheat is sensitive to nitrogen deficiency and very responsive to nitrogen fertilization. Adequate supply of nitrogen improves the yield components and ultimately increases the grain yield. Soil application of nitrogen is a traditional method to supply nitrogen to plants. Sometimes, the availability of urea becomes inadequate for the farmers at sowing time. In such situation the foliar application of plant nutrient is effective and economical for some crops (Nafees *et al*., 1993). Furthermore it has been observed that fertilizer efficiency particularly urea application through soil is not as effective as if it is applied to plants through foliage along with soil application (Mosluh *et al.,* 1978), because only 20 to 50% of the soil applied nitrogen is recovered by annual crops (Bajwa, 1992). Even several researchers have shown that foliar nitrogen application has a higher recovery rather than soil application (Shim *et al.*, 1972; Klein and Weinbaun, 1985; Weinbaum, 1988). However, it is still believed that soil nitrogen application cannot be completely substituted by foliar application

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(Mengel, 2002) but can reduce the loss in yield due to non-availability of nitrogen. In addition to fulfill the crop requirement, the combination of soil and foliar nitrogen application may be a more efficient use of N and reduces N losses (Fallahi and Simons, 1996; Khemira *et al*., 1998). So keeping in view the above facts, this study was planned to see the effects of foliar application of urea on wheat yield in case of urea shortage and to minimize the production cost of wheat.

Materials and Methods

A field study was conducted at research area of Soil Chemistry Section, Institute of Soil Chemistry and Environmental Sciences, Ayub Agricultural Research Institute, Faisalabad for three consecutive years i.e. 2009-2010, 2010-2011 and 2011-2012. The experiment was laid out in randomized complete block design (RCBD) with three replications. The following concentrations and time of foliar application of urea were tested.

1. No fertilizer
2. Conventional method of urea application (all nitrogen at sowing)
3. 1% urea (6 sprays, from two leaves stage to booting stage)
4. 2% urea (3 sprays, at two leaves stage, tillering and booting stage)
5. 3% urea (2 sprays, at tillering and booting stage)
6. 1/2 soil applied + 2% urea (2 sprays, at tillering and booting stage)

Table 1: Average fertility status of field used for study

Soil depth (cm)	pH_s	EC_e (dS m^{-1})	O.M (%)	Available P (mg kg^{-1})	Extractable K (mg kg^{-1})	Textural class
0-15	7.68	1.52	0.86	13.17	253	Sandy clay
15-30	7.60	1.37	0.66	11.84	220	loam

Recommended NPK dose by Agriculture department was applied at 120-90-60 kg ha^{-1} using urea, SSP and MOP as source, respectively. All NPK (nitrogen for soil application) was applied at the time of sowing. Prior to experimentation, composite soil samples were taken using auger from 0-15 and 15-30 cm depth. The air dried, crushed and sieved (2 mm) soil samples were stored in plastic bottles and then analyzed for physico-chemical properties using standard procedures.

The pH of soil paste and electrical conductivity of the soil extract was measured by method of Mclean, 1982. Soil organic matter contents were estimated following the method described by Walkley, 1947, which involves reduction of potassium dichromate by organic carbon compounds. Potassium was determined on flame photometer (Rowell, 1994) while phosphorus was measured on spectrophotometer at 880 nm λ using sodium bicarbonate extraction (Rowell, 1994) and textural class by using hydrometer method (Bouyoucos, 1962). The pooled soil analysis data of the field is given in Table 1.

Data regarding yield components viz. plant height, tiller $plant^{-1}$, spike length, number of grains $spike^{-1}$ and 1000 grain weight were noted. After harvesting at maturity, the grain yield data were recorded and grain samples were dried at 70 ^oC till constant weight in an oven and ground in a Wiley micro mill. For nitrogen estimation, the dried ground material (0.5 g) was digested in sulphuric acid using digestion mixture ($CuSO_4$, Se and $FeSO_4$), distilled and titrated against 0.1N H_2SO_4 (Jackson, 1962). Nitrogen uptake by grain was calculated by multiplying grain yield with nitrogen concentration (%) in grain. Cost benefit ratio of different treatments was calculated as described by CIMMYT (1998). Statistical analysis was done by using the M-Stat computer program. ANOVA test following by least significance difference (LSD) test was used to determine the difference among the treatment means ($p < 0.05$).

Results and Discussion

Wheat yield components

The 3 year pooled yield contributing characters viz. plant height, number of tillers $plant^{-1}$, spike length, grain $spike^{-1}$ and 1000 grain weight were recorded. The data given in Table 2 showed that wheat responded significantly to treatments. The maximum plant height (113.6 cm) was observed in treatments where all urea was applied as soil application, which was statistically similar to treatment where ½ urea was soil applied at sowing + 2 sprays of 2% urea at tillering and booting stage was done. The minimum plant height (88.6 cm) was recorded where no fertilizer was applied. The number of tillers $plant^{-1}$ is important parameter which contributes towards grain yield of wheat. It is interesting that number of tillers $plant^{-1}$ were same in treatment where all urea was applied at sowing and where ½ urea was applied at sowing + 2 sprays of 2% urea was done at tillering and booting stage. The results revealed that foliar application of urea improved tillering of wheat crop than no fertilizer treatment. The maximum spike length was observed in treatment where ½ urea was applied at sowing

+ 2 sprays of 2% urea were sprayed at tillering and booting stage (14.8 cm). The results of 2 sprays of 3% urea gave similar spike length. The minimum spike length of 13.6 cm was observed in control where no fertilizer was applied. The number of grains spikes^{-1} are also important to predict the yield of wheat grain. The highest number of grains spike^{-1} (39) was found in treatment where all urea was applied as soil application at sowing following the treatment where ½ urea was applied at sowing+ 2 sprays of 2% urea at tillering and booting stage (35 grain spaike^{-1}). Table 2 showed improvement in number of grain spike^{-1} by foliar application of urea of either concentration. The results indicated that the more spray of lower concentration of urea (6 sprays of 1% urea) was less effective in improving the number of grains spike^{-1} than less number of sprays of higher concentration. Chopra and Chopra (2004) reported that nitrogen had significant effects on yield attributes such as plant height, panicle plant^{-1} and 1000 grain weight with increasing levels of N up to 120 kg N ha^{-1}. Khan *et al*., 2009; Gul *et al*., 2011 and Saeed *et al*., 2012 also supported the same theory that foliar application of urea significantly increased plant height, spike length, number of grains spike^{-1}, 100 grain weight, grain yield and nitrogen uptake by crop when sprayed at tillering, stem elongation and booting stage. The 1000 grain weight indicated the vigor of grain as an important yield contributing factor. The results revealed that all soil application of urea and ½ soil + 2 spray of 2% urea gave statistically similar 1000 grain weight. The foliar application of urea of either concentration improved the grain weight over no fertilizer treatment.

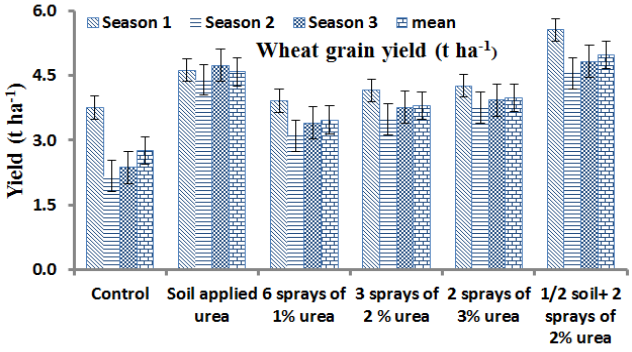

Figure 1: Effect of soil and foliar application of urea on wheat grain yield

The year wise and three year pooled wheat grain yield data are presented in figure 1. The three year pooled results showed that soil and foliar application of urea showed significant influence on grain yield of wheat. The highest grain yield (4.97 t ha^{-1}) was recorded where ½ soil urea + two sprays of 2% urea was applied which was followed by all soil applied urea (4.58 t ha^{-1}). However, both treatments were statistically at par with each other. The minimum grain yield of 2.79 t ha^{-1} was recorded where no fertilizer was applied. Among foliar applications, higher concentration of urea i.e. 2 and 3% gave more yield than 6 sprays of 1% urea. Chopra and Chopra (2000) reported that application of either 80 or 120 kg N ha^{-1} improved the entire yield attributes compared to control. Results of grain yield revealed that application of 2% urea solution is not enough to produce good yield (3.80 t ha^{-1}), while with ½ soil application + 2% urea solution, the performance was better (4.97 t ha^{-1}). Mosluh *et al.* (1978) showed that foliar feeding of urea in combination with soil application to wheat crop gave significant increase in the grain yields. Swenson *et al*. (2009) proved that foliar application before the booting stage resulted in significantly higher yields. These results suggest that if urea is not available at sowing then 2 to 3 sprays of 2-3% urea at two leaves, tillering and booting stage can minimize the losses in wheat grain yield. The lower concentration of urea (1% six sprays) is not much effective.

Nitrogen concentration and uptake by wheat grain

The samples of wheat grain at harvesting were collected each year to monitor the nitrogen concentration and uptake. The year wise and pooled results are presented in figure 2 and 3. The pooled data showed that nitrogen concentration in grain increased by foliar application of nitrogen than soil application. Similarly, in case of uptake, the ½ soil + 2 sprays of 2% urea gave maximum concentration of nitrogen and uptake. The N content in treatment of 1% urea spray, 3% urea spray and ½ urea at sowing + 2% foliar spray were statistically similar. Tea *et al.* (2007) reported that foliar nitrogen fertilization on wheat at optimum timings increased the remobilization of urea (N) to grain and increased grain protein content. The results also are in agreement with Mosluh *et al.* (1978) and Swenson *et al.* (2009).

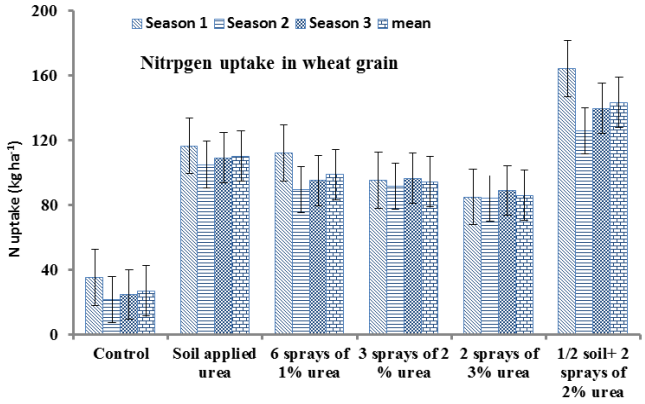

Figure 2: Effect of soil and foliar application of urea on nitrogen uptake by wheat grain

Table 2: Effects of soil and foliar application of urea on yield contributing parameters

Treatment	Plant height (cm)	Tillers per plant	Spike length (cm)	Grains per spike	1000 grain weight (g)
Control	88.6e	5b	13.6c	20e	35.9d
Soil applied urea	113.6a	9a	14.6ab	39a	44.0ab
6 sprays of 1% urea	98.2d	6b	12.5d	25d	41.4bc
3 sprays of 2 % urea	103.2c	6a	14.0bc	29c	40.4c
2 sprays of 3% urea	108.0bc	7b	14.2abc	30c	43.1bc
½ soil + 2 sparys of 2% urea	111.1ab	9a	14.8a	35b	45.7a

Means for each parameter sharing similar letters do not differ significantly at p = 0.05

Table 3: Cost benefit ratio

Treatment	Cost of urea fertilizer ha^{-1} (Rs)	Yield (t ha^{-1})	Wheat price	Net price (Rs)	CBR
Control	0	2.76	98437	--	---
Soil applied urea	9396	4.58	121275	22838	2.43
6 sprays of 1% urea	950	3.47	102637	4200	4.42
3 sprays of 2 % urea	950	3.80	108937	10500	11.05
2 sprays of 3% urea	950	3.98	111825	13388	14.09
½ soil + 2sparys of 2% urea	5313	4.82	145687	47250	8.89

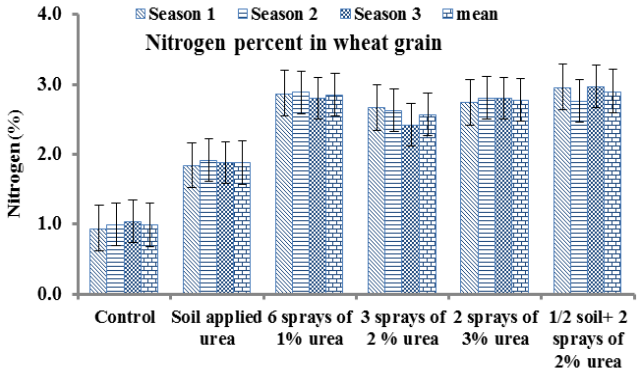

Fig 3: Effect of soil and foliar application of urea on nitrogen concentration in wheat grain

Cost benefit ratio

Three year pooled wheat grain yield data were used for calculating the cost benefit ratio. The analysis (Table 3) showed that the highest net return was obtained from ½ soil and 2 sprays of 2% urea (47250 rupees) and the lowest one (4200 rupees) was from the 6 sprays of 1% urea. Sudhakar *et al*. (2001) found that there was a significant increase in grain yield, straw yield, net return and cost benefit ratio with each increment of N application up to 125 kg ha^{-1}.

The cost benefit ratio indicates that foliar application of urea at tillering and booting gave maximum return however grain yield in both of these two cases was significantly lower than soil application of urea. The integration of soil and foliar application of urea not only improved the CBR but also gave comparable yield to total soil application of urea.

Conclusion

The results indicate that in case of shortage of urea at the time of sowing or at 2nd dose of application at 1st irrigation, the losses in grain yield can be minimized by foliar application of 2 to 3% urea solution at two leaves, tillering and at booting stage. The integrated use of soil and foliar application of urea not only saves the cost of input but also gives comparable results to total soil application of urea.

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