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FOLIAR NITROGEN MANAGEMENT FOR IMPROVING GROWTH AND YIELD OF DRYLAND WHEAT

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ABSTRACT. Foliar nitrogen (N) application is considered an important factor affecting phenology, growth, yield, and yield components of dryland wheat (*Triticum aestivum* L.). A field experiment was conducted to study effects of foliar N on dryland wheat (cv. Prisabk-2004) at the Agronomy Research Farm, The University of Agriculture Peshawar, Pakistan, during winter 2010-2011. The experiment was laid out in randomized complete block design using four replications. A plot size of 3 m by 4 m, having 8 rows, 4 m long and 30 cm apart was used. A total of 80 kg N ha^{-1} in the form of urea was applied. Out of 80 kg N ha^{-1}, 70 kg N ha^{-1} was applied to the soil at sowing time, and the remaining 10 kg N ha^{-1} was applied in the form of foliar spray (2% N). The required foliar N was applied in various combinations (splits) at different growth stages viz. 30, 60, 90 and 120 days after emergence (DAE). Phenological development (days to anthesis and physiological maturity) was delayed, yield components and yield increased significantly ($p \leq 0.05$) with foliar N over control (water spray without N). Wheat grain yield increased to the highest level (4427 kg ha^{-1}) when 100 % foliar N was applied (no split) at 90 DAE, followed by 4050 kg ha^{-1} at 120 DAE, while the control (no foliar N) resulted in the lowest grain yield (2573 kg ha^{-1}). We concluded from this study that 2 % foliar N application in a single split either at 90 or 120 DAE could improve wheat productivity under dryland condition.

Key words: Wheat; Yield; Yield components; Foliar N; Moisture stress.

INTRODUCTION

Improper water and nutrients management are the two main factors that adversely affect the growth and crop productivity under moisture stress (drought) condition in the

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Khyber Pakhtunkhwa province of Pakistan (Amanullah *et al.,* 2014). Several potential benefits of providing nitrogen (N) to cereals *via* the foliage as urea solution include reduced N losses through denitrification and leaching, compared with N applications to the soil the ability to provide N, when root activity is impaired, e.g. in saline or dry conditions, and uptake late in the season to increase grain N concentration. Foliar urea applications increase grain yield, particularly when applied before flag leaf emergence and when N availability is limiting (Gooding and Davies, 1992). Applications of N near flowering increase post flowering N uptake, grain protein content, and grain protein concentration (Banziger *et al.,* 1994). 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 and Davies, 1992). A supplemental dose of 7 kg N ha^{-1} as urea spray significantly increase maize grain yield (Singh *et al.,* 2005). Foliar applications of urea to chlorotic leaves of N-deficient maize restored both normal chlorophyll content and stomatal behavior of leaves (Shimshi, 1967). 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 full N (100 kg N ha^{-1}) as basal dose but foliar spray without basal N reduced the yield of maize by 15 percent compared to normal practices (Islam *et al.,* 1996). Foliar N significantly increased plant height, while days to tasseling and maturity decreased with decreasing level of N (Karim *et al.,* 1983). Grain and stover yields, number of grains per ear, 1000 seed weight, and grain weight per ear increased significantly up to 6% foliar N (Sanjeev *et al.,* 1997). Late season foliar N application had a significant effect on maize yield, total grain N, straw yield and total straw N (Woolfolk *et al.,* 2002). Urea sprays did not increase N content in leaves but decreased the accumulation of carbohydrates in stalks and appeared to interfere with indigenous N metabolism. These observations explain the general ineffectiveness of foliar-N treatments of maize (Below *et al.,* 1984). The amount of injury by foliar N is modified by additions of sugar, calcium hydroxide, and potassium bicarbonate. Yield response of corn to foliar applied N is no greater than to the same amount of N applied as a side dressing. When injury occurs the yield response is reduced. Ammonia or nitrites did not appear to cause the injury but some product or a number of products of ammonia metabolism did. The beneficial effect of sucrose is believed to be due to the decreased rate of urea absorption and an increased rate of its translocation within the plant (Foy *et al.,* 1953). Studies on the levels and timings of foliar N on dryland wheat is lacking. The present study was, therefore, initiated to determine the best level and timing of foliar application of N to improve growth and increase yield of dryland wheat.

MATERIAL AND METHODS

Field experiment was conducted in order to investigate the effects of foliar nitrogen (2% N) as urea applied at 30, 60, 90 and 120 days after emergence (DAE) in one, two, three and four equal splits on the growth and yield of dryland wheat (*Triticum aestivum* L., cv. Prisabk-2004) at The Agriculture Research Farm of The University of Agriculture Peshawar (Pakistan), during winter 2010-2011. The detail of treatments combination is given in *Table 1*. The experiment was laid out in randomized complete block design using four replications. A plot size of 3 m by 4 m, having 8 rows, 4 m long and 30 cm apart was used. A uniform basal dose of 50 kg ha^{-1} P_2O_5 as single super phosphate was applied at seedbed preparation. A total of 80 kg N ha^{-1} in the form of urea was applied including 70 kg N ha^{-1} as soil application at sowing time, and the remaining 10 kg N ha^{-1} was applied in the form of foliar spray (2% N).

Table 1 - Foliar N (2 %) application time (30, 60, 90 and 120 days after emergence) and number of splits (one, two, three and four equal splits) used in the experiment

Treatments	Application time days after emergence			
	30	60	90	120
T_0	-	-	-	-
T_1	100	-	-	-
T_2	-	100	-	-
T_3	-	-	100	-
T_4	-	-	-	100
T_5	50	50	-	-
T_6	50	-	50	-
T_7	50	-	-	50
T_8	-	50	50	-
T_9	-	50	-	50
T_{10}	-	-	50	50
T_{11}	33	33	33	-
T_{12}	33	33	-	33
T_{13}	33	-	33	33
T_{14}	-	33	33	33
T_{15}	25	25	25	25

Data were recorded on phenological development (days to anthesis and physiological maturity), yield and yield components. Data on days to anthesis and physiological maturity was recorded when more than 50% plants reached anthesis and physiological maturity, respectively. The data on plant height was taken from base to top of the plant for 10 selected plants per plot in each treatments, and then average plant height was worked out. Number of spikes was counted in one meter long row in three different places in each plot, and then it was converted into spikes m^{-2}. From each treatment, 10 spikes were selected and their number of grains was counted after threshing each ear separately, and then average was worked out. Thousand grains were taken at random from the grain lot of each subplot and weighted by electronic balance. This was repeated thrice and then average weight per 1000 grains was calculated and recorded. Data on biological yield was recorded after harvesting the four middle rows from each subplot. The harvested material was dried up to constant weight, weighed by spring balance and converted into biological yield in kg ha^{-1}. The material was then threshed, the seeds were cleaned and weighed and then converted into grain yield in kg ha^{-1}. The harvest index was calculated in percentage according to the following formula:

$$\text{Harvest index} = \text{Grain yield} \div \text{Biological yield} \times 100$$

Statistical analysis

Data was statistically analyzed according to Steel *et al.* (1996) and means were compared using LSD test ($p \leq 0.05$). Microsoft Excel-2010 was used for the statistical analysis of the data.

RESULTS AND DISCUSSIONS

Days to anthesis, days to maturity and tillers m^{-2}

Data regarding days to anthesis, days to maturity and tillers m^{-2} (*Table 2*) revealed that foliar N application time and splits had significantly affected days to anthesis, days to maturity and tillers m^{-2} ($p \leq 0.05$). Anthesis was delayed (129 days), when foliar N was applied in three equal splits (33% each) at 30, 60, 120 days after emergence (DAE). The earliest anthesis of 124 days each was observed in the control plots (water spray with no N) and in those plots in which foliar N was applied in two equal splits (50% each) at 60 and 120 DAE. Plots having foliar N applied in one split at every stage except 120 DAE and three splits at (30, 60, 90 and 30, 90, 120 DAE) took more (175 days) time to maturity, while control plots took less time (171 days) to maturity. Delayed anthesis and maturity probably may be due to late application of N, as N enhance and prolong vegetative growth. The results are in line with Hadi *et al.*, (2012), who reported that N applied in three divided doses and late application of N delayed days to maturity. Amanullah *et al.* (2013) reported that foliar application of urea and CAN (calcium ammonium nitrate) delayed maturity by one day as compared with foliar application of AS (ammonium sulphate). They also reported that foliar-N application at 45 and 60 DAE delayed maturity (94 days) as compared to early application (15 or 30 DAE) which enhanced maturity in maize by two days.

Higher (79) tillers m^{-2} were produced when foliar N was applied as single split at 90 DAE, followed by the plots having foliar N applied in two equal splits at 30 and 90 DAE with 77 tillers m^{-2}. Plots having foliar N applied in three equal splits at 30, 60 and 90 DAE produced lower (49) tillers m^{-2}. Our results are in contrast to those of Hadi *et al.,* (2012), who observed that N applied in three divided doses produced maximum tillers $plant^{-1}$.

Table 2 - Days to anthesis, days to maturity and tillers m^{-2} of wheat as influenced by timing and split application of foliar N under moisture stress condition

Treatments	Days to anthesis	Days to maturity	Tillers m^{-2}
Control or water spray (T_0)	124 DE	171 D	57 HI
100% 30 DAE (T_1)	126 CD	175 A	69 DEF
100% 60 DAE (T_2)	126 AB	175 A	56 HIJ
100% 90 DAE (T_3)	126 AB	175 A	79 A
100% 120 DAE (T_4)	127 BC	174 AB	67 EF
50% 30 DAE + 50% 60 DAE (T_5)	126 CD	172 CD	64 FG
50% 30 DAE + 50% 90 DAE (T_6)	127 B	173 BC	77 AB
50% 30 DAE + 50% 120 DAE (T_7)	125 DE	174 AB	71 CDE
50% 60 DAE + 50% 90 DAE (T_8)	127 BC	174 AB	73 BCD
50% 60 DAE + 50% 120 DAE (T_9)	124 E	172 CD	75 ABC
50% 90 DAE + 50% 120 DAE (T_{10})	126 CD	173 BC	51 JK
33% 30 DAE + 33% 60 DAE + 33% 90 DAE (T_{11})	125 DE	175 A	49 K
33% 30 DAE + 33% 60 DAE + 33% 120 DAE (T_{12})	129 A	173 BC	53 IJK
33% 30 DAE + 33% 90 DAE + 33% 120 DAE (T_{13})	126 CD	175 A	53 IJK
33% 60 DAE + 33% 90 DAE + 33% 120 DAE (T_{14})	127 BC	174 AB	53 IJK
25% 30 DAE + 25% 60 DAE + 25% 90 DAE + 25% 120 DAE (T_{15})	126 CD	172 CD	60 GH
LSD (0.05)	**1.3**	**1.3**	**5.8**

Plant height, grains $spike^{-1}$ and 1000 grains weight

Foliar N splits and its application time had significant effects on plant height, grains $spike^{-1}$ and 1000 grains weight (*Table 3*). Taller plants of 57 cm heights were recorded when foliar N was applied in one split at 90 DAE, however, it was not significantly different from that of three equal N splits at 30, 60, 90 DAE. Shortest plants (42 cm) was produced when foliar N was applied in three equal splits at 30, 60 and 120 DAE followed by control plots (44 cm). Arif *et al.,* (2006) reported significant increase in plant height of wheat crop with foliar application of different nutrients individually or in combination. Maximum plant height was recorded by Parvez *et al.,* (2009) where 4% urea solution was sprayed. Amanullah *et al.* (2013) found tallest plants (204 cm) in maize crop with foliar application of urea, and dwarf plants (190 cm) were observed with water spray (no N). They also found that delayed foliar spray (60 DAE) produced taller plants (203 cm), and the shortest plants (190 cm) were recorded when spray was applied at 15 DAE.

Table 3 - Plant height (cm), grains spike^{-1} and 1000 grains weight (g) of wheat as influenced by timing and split application of foliar N under moisture stress condition

Treatments	Plant height (cm)		Grains spike^{-1}	1000 grains weight (g)
Control (T_0)	44	HI	48 D	31.55 E
100% 30 DAE (T_1)	49	DEFG	51 C	34.10 DE
100% 60 DAE (T_2)	51	BCD	51 C	39.96 A
100% 90 DAE (T_3)	57	A	51 BC	38.16 AB
100% 120 DAE (T_4)	52	BCD	52 ABC	37.74 ABC
50% 30 DAE + 50% 60 DAE (T_5)	46	FGH	52 ABC	36.49 ABCD
50% 30 DAE + 50% 90 DAE (T_6)	52	BCD	51 BC	35.81 BCD
50% 30 DAE + 50% 120 DAE (T_7)	49	DEFG	53 A	35.58 BCD
50% 60 DAE + 50% 90 DAE (T_8)	52	BCD	52 ABC	38.47 AB
50% 60 DAE + 50% 120 DAE (T_9)	50	CDEF	51 BC	34.28 CDE
50% 90 DAE + 50% 120 DAE (T_{10})	51	BCDE	53 A	33.32 DE
33% 30 DAE + 33% 60 DAE + 33% 90 DAE (T_{11})	53	ABC	51 BC	35.95 BCD
33% 30 DAE + 33% 60 DAE + 33% 120 DAE (T_{12})	42	I	53 AB	35.54 BCD
33% 30 DAE + 33% 90 DAE + 33% 120 DAE (T_{13})	55	AB	53 AB	34.10 DE
33% 60 DAE + 33% 90 DAE + 33% 120 DAE (T_{14})	47	EFGH	52 ABC	35.06 BCDE
25% 30 DAE + 25% 60 DAE + 25% 90 DAE + 25% 120 DAE (T_{15})	45	GHI	48 D	37.88 ABC
LSD (0.05)	**7.1**		**1.7**	**3.6**

Maximum (53) grains spike^{-1} were obtained when foliar N applied in two equal splits at 30 and 120 DAE, and at 90 and 120 DAE, followed by (52) produced by plots having three equal N splits at 60, 90 and 120 DAE. Control plots produced minimum (48) grains spike^{-1}. Parvez *et al.,* (2009) reported marked increase in number of grains per spike of wheat when urea was applied as foliar spray. While Mattas *et al.* (2011) examined that application of N in three splits (1/3 at sowing, 1/3 at CRI and 1/3 at boot stage) had significantly increased 1000 grains weight in wheat. Bellido *et al.* (2006) also observed significantly higher number of grains with the late application of N. Amanullah *et al.* (2010) found that grains ear^{-1} in maize increased when foliar urea was sprayed at the rate of 6% at the V12 stage. Foliar N when applied as single split at 60 DAE produced higher 1000 grains weight (39.96 g), followed by two equal splits at 60 and 90 DAE (with 38.47 g) and single split at 90 DAE (with 38.16 g). Lower (31.55 g) 1000 grains weight was recorded in control plots. These results are in line with Sadat *et al.* (2008), who reported that the effect of split application of nitrogen was not significant for 1000 grain weight, while Parvez *et al.* (2009) concluded that the foliar spray of 4% urea solution gave heavier grains.

Biological yield, grain yield and harvest index

Data (*Table 4*) showed that foliar N application times and splits had significantly affected biological yield, grain yield and harvest index. Mean values of the data revealed that higher (9672 kg ha^{-1}) biological yield was recorded when foliar N applied in single split at 90 DAE, however it is not significantly different from the plots having foliar N in single split applied at 120 DAE and three equal splits applied at 60, 90 and 120 DAE and. Control plots produced lower (7573 kg ha^{-1}) biological yield. Sadat *et al.* (2008) concluded that the higher biological yield produced by the treatment having 18% N at land preparation + 36% N at crown root initiation + 46% N at panicle initiation. Alston (1979) reported better vegetative growth with foliar application of N. Among the 16 treatments, application of foliar N full dose (2% N) at 90 days after emergence (DAE) had significantly higher grain yield (4427 kg ha^{-1}), followed by 120 DAE (4050 kg ha^{-1}), and the lowest grain yield (2573 kg ha^{-1}) was obtained when foliar N was not applied (*Table 4*). The planned means comparison indicated that rest plots (all the experimental plots applied with foliar N) had higher grain yield (3481 kg ha^{-1}) than the N-control plots (2573 kg ha^{-1}) as given in *Table 4*. The increase in grain yield in the rest plots was due to the delay in maturity and increase in yield components. The full dose (100% at stage) had higher yield than the two, three and four equal splits. Three and four equal foliar N application had higher grain yield than two equal splits, but three equal splits had more yield than two equal splits (*Table 4*). Amanullah *et al.* (2010) found that grain yield in maize increased when foliar N was applied in three splits and the increase in yield was attributed to delay in maturity, increase in leaf area an, yield components in maize. 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 in wheat (Gooding and Davies, 1992). Parvez *et al.* (2009) found foliar N application beneficial for grain yield.

Highest (46%) harvest index was recorded when foliar N applied as single split at 90 DAE. Control plots and plots having foliar N applied in three equal splits at 30, 60 and 120 DAE showed similar and lowest (34%) harvest index. Mattas *et al.* (2011) concluded that application of nitrogen in three splits had significantly increased harvest index. Amanullah *et al.* (2013) reported that foliar N sources had significant effects, while application time and interaction had no significant effects on the harvest index of maize.

They also reported that foliar N-sources (urea, calcium ammonium nitrate, and ammonium sulphate) had significantly higher harvest index than control (water spray only).

Table 4 - Biological yield (kg ha^{-1}), grain yield (kg ha^{-1}) and harvest index (%) of wheat as influenced by timing and split application of foliar N under moisture stress condition

Treatments	Biological yield (kg ha^{-1})	Grain yield (kg ha^{-1})	Harvest index (%)
Control (T_0)	7573 I	2573 I	34 H
100% 30 DAE (T_1)	7748 GHI	2906 H	37 FG
100% 60 DAE (T_2)	7713 HI	3054 GH	39 CDEFG
100% 90 DAE (T_3)	9572 A	4427 A	46 A
100% 120 DAE (T_4)	9613 A	4050 B	42 BC
50% 30 DAE + 50% 60 DAE (T_5)	9054 BC	3368 EF	37 FG
50% 30 DAE + 50% 90 DAE (T_6)	8202 EFG	3389 EF	41 BCD
50% 30 DAE + 50% 120 DAE (T_7)	8943 CD	3504 CDE	39 DEFG
50% 60 DAE + 50% 90 DAE (T_8)	8534 DE	3505 CDE	41 BCDE
50% 60 DAE + 50% 120 DAE (T_9)	8200 EFG	3223 FG	39 DEFG
50% 90 DAE + 50% 120 DAE (T_{10})	8301 EF	3340 EF	40 CDEF
33% 30 DAE + 33% 60 DAE + 33% 90 DAE (T_{11})	8562 DE	3623 CD	42 BC
33% 30 DAE + 33% 60 DAE + 33% 120 DAE (T_{12})	9489 AB	3219 FG	34 H
33% 30 DAE + 33% 90 DAE + 33% 120 DAE (T_{13})	8051 FGH	3470 DE	43 B
33% 60 DAE + 33% 90 DAE + 33% 120 DAE (T_{14})	9591 A	3701 C	38 EFG
25% 30 DAE + 25% 60 DAE + 25% 90 DAE + 25% 120 DAE (T_{15})	9329 ABC	3438 DEF	37 G
LSD (0.05)	**455**	**222**	**2.7**

Among the N source, CAN with harvest index of 39.0% stood first, followed by AS (38.4%), and control (35.8%) stood in the bottom in terms of harvest index. Delayed application of foliar spray (60 DAE) resulted in higher harvest index (38.5%), and the lowest harvest index (36.9%) was recorded when the spray was applied at 15 DAE. The increase in yield components (grain weight and grains ear^{-1}) and grain yield with foliar N application resulted in higher harvest index in maize and indicating positive relationship of harvest index with yield components and grain yield.

CONCLUSION

Days to anthesis and physiological maturity was delayed, yield components, yield and harvest index of dryland wheat increased when foliar N was applied over control (water spray without N). Dryland wheat productivity could be increased while applying foliar N (2%) in a single split either at 90 or 120 days after emergence of wheat.

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