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Research Article

Influence of foliar urea on the phenology, growth and yield of maize applied at various growth stages

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Abstract

Field trials were carried out for three consecutive years to investigate the influence of foliar urea on maize (*Zea mays* L.) applied at different growth stages at the Cereal Crops Research Institute (CCRI), Pirsabak Nowshera, Khyber Pakhtunkhwa-Pakistan during 2014–16. The experiment was conducted in RCBD with split plot arrangement using four urea levels (N1 = 0, N2 = 3, N3 = 5 and N4 = 7% urea) assigned to main plots and six application timings [AS1 = V7, AS2 =V10, AS3 = R1 Silking, AS4 = V7+V10 (foliar urea applied at both stages), AS5 = V7+R1 and AS6 = V10+R1] allotted to subplots. Phenological characteristics of maize (tasseling, silking, and maturity) were significantly delayed with foliar urea spray @ 7% and when applied at both V7+V10 stages respectively. Earlier days to tasseling, silking, and maturity were recorded in foliar urea control plots and with foliar urea application when sprayed only at R1 stage. Leaf area, plant height, cob length, grains cob^{-1}, 1000 grain weight, stover and grain yields were significantly improved with 7% urea application. Maize growth and yield were significantly enhanced when foliar urea was applied at both V7+V10 stages respectively. It is concluded that urea foliar feeding @ 7% when applied at both V7+V10 stages enhanced and prolonged vegetative growth period of maize and resulted in increased grain yield and yield components of maize.

Keywords: Maize; Foliar urea; Application stage; Growth; Yield and yield components

Introduction

Foliar feeding, referring to the application of plant nutrients to the foliage of plants, has been documented as early as 1844, when foliar iron sulfate spray was applied for the possible remedy of "chlorosis sickness". Foliar feeding has been broadly used and recognized as an important factor of crop production. Although soil fertilization is the most effective and economic way of supplementing the major plant nutrient requirements, foliar feeding has proven to be an excellent method of supplying plant nutrients during short or critical growth stages. The prime purpose of foliar feeding is to delay the natural senescence shortly after the reproductive growth stages **[1]**. Foliar feeding during crop period when rate of photosynthesis declines and nutrient absorption occur aids in the translocation of nutrients into seed, fruit, tuber or vegetative production. Secondly, foliar feeding

effectively influences the vegetative growth periods by reducing the induced stress of adverse growing conditions and limited nutrient availability [1].

Post flowering N uptake and grain protein contents were improved with near flowering N application **[2]**. Foliar urea when sprayed at anthesis and during flowering had increased grain N content **[3]**. Maize grain yield was significantly improved with urea spray as a supplemental dose at the rate of 7 kg N ha^{-1} **[4]**. Significantly higher grains ear^{-1}, 1000 grain weight, grain and stover yield were recorded with 6% N **[5]**. Foliar N when applied during late season had a significant effect on total grain N, grain yield, total straw N and straw yield **[6]**. Foliar N significantly increased plant height, while earlier days to tasseling and maturity were observed with the decreasing N levels, whereas significantly higher plant was produced with foliar N fertilization **[7]**.

Foliar urea spray had no significant effects on grain and stover yield probably due to the poor utilization of urea N applied after anthesis to improve accumulation of dry matter **[8]**. Significantly higher plant height, cob length, grains cob^{-1} and grain weight were recorded with increasing N levels **[9]**. The chlorotic leaves of N deficient maize regained their normal chlorophyll content and stomatal function with foliar urea application **[10]**.

The application of foliar urea at the rate of 6% delayed days to tasseling, silking and maturity and improved yield and yield components of maize **[11]**. Application of urea through foliar spray had increased grain protein content of barley more effectively than broadcast **[12]**. Significant effects of nitrogen management have been reported on the growth, phenology and grain yield of maize **[13, 14]**.

Studies on the most effective levels of foliar urea and the critical growth stages of maize for foliar urea application in this agro-ecological zone of Khyber Pakhtunkhwa province of Pakistan have not been carried out. Therefore, this study was designed to investigate the comparatively more effective levels of foliar urea and their appropriate application stages for enhancing growth and yield of maize.

Materials and methods

Experimental trials were conducted at the Cereal Crops Research Institute (CCRI), Pirsabak Nowshera, Khyber Pakhtunkhwa-Pakistan, during 2014-16. The climate of Nowshera is prevailed by hot relatively long summers and cold but short winters. The institute is situated on the left bank of river Kabul about 1600 km north of Indian Ocean at 34° N latitude, 72° E longitude and has an altitude of 288 m above sea level. The Soil was calcareous in nature, sandy loam, low in AB-DTPA extractable P (3.5 mg kg^{-1}), organic matter (0.85%), alkaline in reaction (pH 8.0) and moderate in AB-DTPA extractable K (90 mg kg^{-1}). Nitrogen content of soil was also low and measured about 0.085% before the experiment. The mean annual rainfall varies from 450 to 750 mm. Erratic rainfalls occurred mostly in spring in March and particularly in summer from June to August. Mean temperature of the crop growth season was 30.85±3°C during summer 2014-16, however the maximum mean temperature was 36.8±3°C and minimum was 24.6±3°C, with a relative humidity 57.5%.

The experiments were conducted for three consecutive years in randomized complete block design with split-plot arrangement using three replications. Four urea levels, N1 = control, N2 = 3%, N3 = 5%, and N4 = 7%, were assigned to main plots and six application stages, AS1 = V7 (collar of 7^{th} leaf was visible), AS2 = V10 (collar of 10^{th} leaf was visible), AS3 = R1 (silks were visible), AS4 = V7+V10 (foliar urea was applied at both stages respectively), AS5 = V7+R1 and AS6 = V10+R1, were allotted to

subplots. Each subplot consisted of 6 rows, 5 m long with row to row distance of 75 cm and plant to plant distance of 20 cm. Basal doze of N-P-K was applied at the rate of 60-90-60 kg ha^{-1} at the time of sowing as urea (46% N), single super phosphate (18% P_2O_5) and sulfate of potash (50% K_2O) respectively. Maize variety Jalal-2003 was used as a test crop. All required cultural practices were uniformly applied to all experimental plots.

Urea solution for each treatment was prepared by dissolving the respective calculated amount of urea in six-liter water sufficient to fully wet one experimental unit when sprayed. Foliar urea sprays were applied at the specified growth stages during late evening and early morning hours when environmental conditions were warm, moist and calm which favor highest tissue permeability.

Days to tasseling and silking were counted from the date of emergence till 50% tassels and silks appeared in each treatment. Days to maturity were counted from sowing till the plants were fully matured. Plant height of ten randomly selected plants was measured from ground level to top in each subplot and then averaged. Average leaf area was determined by measuring the length and width of five middle leaves from ten randomly selected plants in each subplot using the formula: Average Leaf area = Leaf L x Leaf W x 0.75 **[14]**. Cob length of ten randomly selected cobs was measured from each subplot and then averaged. From each treatment ten cobs were randomly selected and the number of grains cob^{-1} was counted and then averaged. Grain weight was determined by weighing 1000 grains randomly taken from the grain lot of each subplot. The stover of maize harvested from all six rows of each subplot was dried and weighed to estimate stover yield. Grain yield from each subplot was determined using the following formula **[15]**.

$$\text{Grain Yield (Kg plot}^{-1}) = \frac{(100\text{-Moisture (\%) at harvest}) \times \text{Fresh ear weight plot}^{-1}\text{ (Kg)} \times \text{Shelling(\%)}}{(100\text{-Store grain moisture (15\%)}) \times 100}$$

$$\text{Grain Yield (t ha}^{-1}) = \frac{\text{Grain yield (Kg plot}^{-1}) \times 10000\ m^2 \times \text{ton}}{\text{Plot size } (m^2) \times 1\text{ ha} \times 1000\text{ Kg}}$$

Analysis of variance procedure was followed for the statistical analysis of data based on randomized complete block design with split plot arrangement **[16]**. Means were compared using least significant difference (LSD) test at $P \leq 0.05$ upon significant F-test.

Results

Phenology and growth

Phenology (days to tasseling, silking and maturity) and growth of maize (plant height and average leaf area) were significantly improved with foliar urea feeding at various growth stages (Table 1). Days to tasseling were delayed to 53 days with the application of foliar urea @ 7%, followed by 51 days to tasseling when foliar urea was applied @ 5%. Earlier days to tasseling (47) were recorded in control plots. Days to tasseling were prolonged to 53 days when foliar urea was applied at both V7+V10 stages respectively. Application of foliar urea at both V7+R1 stages resulted in 51 days to tasseling on a par with when foliar urea was sprayed only at the V7 stage. Earlier days to tasseling (47) were observed when urea was applied only at R1 stage.

Foliar urea levels and application stages had a significant effect on days to silking (Table 1). Days to silking were delayed to 55 days when foliar urea was applied @ 7%, followed by 53 days to silking when sprayed @ 5%. Earlier days to silking (49) were observed in control plots. Days to silking were advanced to 55 days when foliar urea was sprayed at both V7+V10 stages respectively, followed by foliar urea spray at both V7+R1 stages resulting in 53 days to silking. Earlier days to silking (49) were observed when urea was applied only at R1 stage.

Days to maturity were significantly delayed with foliar urea application at various growth stages (Table 1). Days to maturity were delayed to 97 days when foliar urea was applied @ 7%, followed by 95 days to maturity when sprayed @ 5%. Earlier days to maturity (90) were observed in control plots. Foliar urea sprays delayed days to maturity (97) when applied at both V7+V10 stages respectively, followed by days to maturity (95) when sprayed at both V7+R1 stages. Earlier days to maturity (90) were observed when foliar urea was applied only at R1 stage.

Foliar urea levels and application stages produced a significant effect on plant height (Table 1). Plant height was 177 cm tall when foliar urea was applied @ 7%. Foliar urea application @ 5% produced 169 cm tall plants on a par with (165 cm) when applied @ 3%. Lowest plant height 158 cm was produced in control plots. Spray of foliar urea at both V7+V10 stages resulted in 176 cm tall plants on a par with foliar urea application at both V10+R1 stages with 172 cm plant height. Plant height was lowest 160 cm when foliar urea was sprayed only at R1 stage.

Average leaf area was significantly affected by foliar urea levels and application stages (Table 1). Average leaf area was 353 cm^2 wider when applied with foliar urea @ 7%. Foliar urea application @ 5% produced 341 cm^2 broader average leaf area on a par with (336 cm^2) when sprayed @ 3%. Lowest average leaf area 318 cm^2 was produced in control plots. Foliar urea when sprayed at both V7+V10 stages produced 356 cm^2 wider average leaf area. Application of foliar urea spray at both V10+R1 stages resulted in 346 cm^2 average leaf area as compared to the lowest 323 cm^2 average leaf area produced when foliar urea was applied only at R1 stage.

Table 1. Tasseling (days), silking (days), maturity (days), plant height (cm), and avg. leaf area (cm^2) of maize as affected by foliar urea application at different growth stages

Treatments	Tasseling	Silking	Maturity	Plant height	Leaf area
Foliar Urea levels (N)					
N1=Control	47	49	90	158	318
N2=3% Urea	50	51	93	165	336
N3=5% Urea	51	53	95	169	341
N4=7% Urea	53	55	97	177	353
$LSD_{(0.05)}$	0.76	0.51	0.52	3.44	7.48
Application stages (AS)					
AS1=V7	51	52	94	163	326
AS2=V10	49	51	93	164	336
AS3=R1	47	49	90	160	323
AS4=V7+V10	53	55	97	176	356
AS5=V7+R1	51	53	95	168	337
AS6=V10+R1	50	52	93	172	346
$LSD_{(0.05)}$	0.80	0.92	0.92	4.33	6.15

All the interaction effects b/w foliar urea levels and application stages were insignificant

Grain yield and yield components

Grain yield, stover yield and yield components of maize were significantly affected by foliar urea levels and application stages. Effect of foliar urea levels and application stages was found significant on cob length (Table 2). Foliar urea spray @ 7% produced 18.6 cm long cobs on a par

with foliar urea spray @ 5% which produced 17.8 cm long cobs as compared to the lowest 14.7 cm cob length produced in control plots. Highest cob length of 17.8 cm was produced when foliar urea was applied at both V7+V10 stages respectively, followed by 17.2 cm cob length produced with foliar urea spray at both V10+R1 stages. Lowest cob length of 15.9 cm was observed when foliar urea was applied only at R1 stage.

Grains cob^{-1} were significantly influenced with application of foliar urea levels and application stages (Table 2). Highest number of gains cob^{-1} (443) was produced when foliar urea was applied @ 7% on a par with grains cob^{-1} (440) when sprayed @ 5%. Lowest number of grains cob^{-1} (378) was produced in control plots. Number of grains cob^{-1} (445) were highest when foliar urea was applied at both V7+V10 stages respectively, followed by the number of grains cob^{-1} (437) with foliar urea spray at both V10+R1 stages. Lowest number of grains cob^{-1} (398) was produced when foliar urea was sprayed only at R1 stage on a par with grains cob^{-1} (400) when applied only at V7 stage.

Foliar urea levels and application stages had significantly affected 1000 grain weight (Table 2). Highest 1000 grain weight (307 g) was recorded when foliar urea was applied @7% on a par with 1000 grain weight (296 g) when sprayed @ 5%. Lowest 1000 grain weight (251 g) was produced on control plots. Application of foliar urea at both V7+V10 stages produced the highest 1000 grain weight (304 g), followed by 1000 grain weight (294 g) when foliar urea was sprayed at both V10+R1 stages respectively. Lowest 1000 grain weight (270 g) was recorded with foliar urea spray only at R1 stage.

Significant effects of foliar urea levels and application stages were found on stover yield of maize (Table 2). Maximum stover yield (11.1 t ha^{-1}) was produced when foliar urea was applied @ 7% on a par with the stover yield (10.8 t ha^{-1}) when foliar urea was sprayed @ 5%. Lowest stover yield (8.8 t ha^{-1}) was produced in control plots. Foliar urea spray at both V7+V10 stages resulted in highest stover yield (11.3 t ha^{-1}) on a par with stover yield (10.8 t ha^{-1}) when foliar urea was sprayed at both V10+R1 stages. Lowest stover yield (9.5 t ha^{-1}) was produced when foliar urea was applied only at V7 stage.

Grain yield of maize was significantly affected by foliar urea levels and application stages (Table 2). Highest grain yield (4.4 t ha^{-1}) was produced with the application of foliar urea @ 7%, followed by grain yield (4.2 t ha^{-1}) when foliar urea was applied @ 5%. Lowest grain yield (3.3 t ha^{-1}) was observed in control plots. Application of foliar urea spray at both V7+V10 stages produced the highest grain yield (4.7 t ha^{-1}), followed by grain yield (4.2 t ha^{-1}) when foliar urea was sprayed at both V10+R1 stages. Lowest grain yield (3.6 t ha^{-1}) was produced with foliar urea spray only at R1 stage.

Table 2. Cob length (cm), grains cob^{-1}, 1000 grain weight (g), stover yield (t ha^{-1}) and grain yield (t ha^{-1}) of maize as affected by foliar urea application at different growth stages.

Treatments	Cob length	Grains cob^{-1}	1000 grain weight	Stover yield	Grain yield
Foliar Urea levels					
N1=Control	14.7	378	251	8.8	3.3
N2=3% Urea	16.5	424	284	9.9	4.1
N3=5% Urea	17.8	440	296	10.8	4.2
N4=7% Urea	18.6	443	307	11.1	4.4
LSD$_{(0.05)}$	1.23	14.46	12.01	0.97	0.13
Application stages (AS)					
AS1=V7	16.5	400	276	9.5	3.7
AS2=V10	17.4	421	287	10.1	4.0
AS3=R1	15.9	398	270	9.3	3.6
AS4=V7+V10	17.8	445	304	11.3	4.7
AS5=V7+R1	16.8	425	277	9.6	3.8
AS6=V10+R1	17.2	437	294	10.8	4.2
LSD$_{(0.05)}$	0.79	6.91	7.21	0.69	0.24

All the interaction effects b/w foliar urea levels and application stages were insignificant

Discussion

Application of foliar urea @ 7% when applied at both V7+V10 growth stages delayed days to tasseling, silking and maturity. Late season application of foliar urea had delayed days to tasseling, silking and maturity in maize [7, 9, 11]. Increased N application in various splits had enhanced photosynthesis [17] and delayed days to tasseling and silking in maize [14, 18]. Foliar urea sprays at both V7+V10 growth stages improved plant height and leaf area when applied @ 7% possibly due to the increased vegetative growth of maize. Foliar urea application had increased plant height in maize when applied late during the growth period [11]. Application of foliar urea had enhanced plant height and leaf area in maize [10]. Taller plant height was observed in maize when sprayed with foliar urea at 60 DAE as compared to control (water spray) [19]. Average leaf area was improved with foliar urea spray @ 7% and when applied at both V7+V10 growth stages. Delayed application of foliar urea had enhanced vegetative growth and improved leaf area in maize [11]. Foliar urea spray had resulted increase in the mean leaf area [10]. In an earlier study it had been reported that foliar N application time had significant effects on mean leaf area of maize [19].

Highest cob length was observed with foliar urea spray @ 7% and when applied at both V7+V10 stages. The increase in cob length might be due to the delayed growth period and improved leaf area with the application of foliar urea. Highest ear length was recorded with foliar application of NPK (125%) fertilizer [20]. Foliar urea spray @ 7% and when applied at V7+V10 growth stages improved the number of grains cob^{-1}. Application of foliar urea enhanced vegetative growth, plant height and leaf area of maize especially when sprayed @ 7% during the late growth stages which might have improved the number of grains cob^{-1}. Earlier studies [21] suggested that application of foliar N spray increased number of grains cob^{-1} in maize [5, 11]. In wheat crop, highest numbers of grains spike-1 were reported [22] with the application of foliar NPK sprays. Our results are in line with the findings which found significant

effects of N application on the number of grains cob^{-1} in maize [9]. Higher 1000 grain weight was recorded with foliar urea application @ 7% and when applied at V7+V10 growth stages. The increase in grain weight might be due to the longer grain filling period resulting in more photosynthates allocation to the grains. About 90% of the required N for ear development is allocated from the stored N in stalks and leaves during anthesis and grain filling stages [23]. Foliar N application had increased photo-assimilates accumulation in grains resulting in improved grain weight of maize [11, 24]. Application of nitrogen at higher rates had increased photo assimilate formation and improved grain weight [5, 25, 26]. Significantly higher stover yield was obtained with foliar urea spray @ 7% and when applied at both V7+V10 stages. The vigorous vegetative growth and improved plant height and leaf area might have resulted in increased stover yield of maize. Application of foliar N during the late growth stages had improved stover yield of maize [6, 11, 27]. Application of late season foliar N and P had significantly influenced straw yield in wheat [28]. Higher grain yield was produced when foliar urea was sprayed @ 7% at V7+V10 growth stages. The improved vegetative growth period, average leaf area, grains cob^{-1} and 1000 grain weight might have resulted in higher grain yield of maize. Significantly higher grain yield had been reported in maize with foliar urea application [3, 27]. Foliar urea application had resulted in significantly higher grain yield of maize [4, 11, 29].

Conclusion

Foliar urea sprays, as a supplement to the routine soil N fertilization, improved vegetative growth period and grain yield when applied during periods of slow growth and flowering. Our results revealed that foliar urea sprays at the rate of 7% significantly enhanced growth, grain yield and yield components of maize when applied at both V7+V10 growth stages respectively.

Authors' contributions

Conceived and designed the experiment: S Ullah, Performed the experiment: S Ullah RM Khan & HU Rahman, Analyzed the data: S Ullah, Contributed reagents/ materials/ analysis tools: S Ullah RM Khan & HU Rahman, Wrote the paper: S Ullah.

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