

Yield and Yield Components of Two Winter Wheat (*Triticum aestivum* L.) Cultivars in Response to Rate and Time of Foliar Urea Application

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ABSTRACT

Foliar urea application is one of the nitrogen (N) application methods in cereal grain crops. Yield and yield components may be affected by foliar urea application. To investigate the effect of rate and time of such treatment on yield and yield components of two winter wheat cultivars, a field experiment was conducted at Badjgah, Agricultural Research Farm (29° 36' N, 52° 32' E) of Shiraz University, Shiraz, Iran during 1998-99 growing season. The experimental treatments were two winter wheat cultivars ('Phalat' and 'Marvdasht'), five levels of foliar urea application (0, 8, 16, 24 and 32 kg N ha⁻¹) at three times of application (pre-anthesis, anthesis and post-anthesis). The experimental design was a randomized complete block one with treatments arranged as split-plot factorial with three replicates. The results showed that cultivars responded differently to the rate of foliar N feeding so that, over the growth stages, Marvdasht cultivar produced significantly greater grain yield (+19%) by application of 8 kg N ha⁻¹, whereas, the Phalat cultivar had greater grain yield (+27%) when it was supplied by 16 kg N ha⁻¹. Increase in grain yield was mainly due to an increase in number of grains ear⁻¹. The fertile ears m⁻² and mean grain weight were not significantly affected by foliar urea feeding, however, the harvest index and biological yield were increased. The pre-anthesis foliar feeding with urea resulted in higher yields as compared with later applications. Also the early foliar urea feeding increased the harvest index from 42.4% to 46.9% at 32 kg N ha⁻¹ in Marvdasht cultivar. The results of the present investigation also suggest that late foliar application could decrease nitrogen use efficiency.

Keywords: Foliar N application, Grain yield, Winter wheat.

INTRODUCTION

Foliar application of urea has been demonstrated to be an effective method of nitrogen (N) fertilization in grain cereals since 1950's [6]. If the majority of the urea is taken up through the foliage, it has been suggested that, at least in short terms, it would not contribute greatly to nitrate leaching or denitrification [12]. The positive effects of foliar urea application on grain yield have been reported for a wide range of sites and climates [1,4,6,18]. All grain yield components might be improved by foliar N feeding, for

example, ear number and/or grain number per ear during and at the end of tillering [10,16]; grain number per ear and/or average grain weight between fully expanded flag leaf stage and ear emergence [14,20]; and mean grain weight at and after anthesis [18,20]. While Singh and Seth [17]; found that there was no difference in N uptake and dry matter production between N topdressing and foliar application, Strong [20] emphasized that the best method of N fertilization depends upon the time of application. Sarandon and Gianibelli [16] reported that foliar urea application at the end of tillering in wheat increased the grain number per m²,

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**Table 1.** Soil physico-chemical characteristics of the experimental site.

Characteristics	
Silt (%)	48
Clay (%)	30
Sand (%)	22
Soil texture	Silty clay loam
Potassium (mg kg ⁻¹)	650
Phosphorus (mg kg ⁻¹)	17.96
Soil pH (Saturated paste)	7.8
Organic carbon (%)	0.61
Electrical conductivity (dS m ⁻¹)	0.72
Total nitrogen (%)	0.05

dry matter yield, grain yield, harvest index and total N uptake. Spraying at anthesis although increased the grain yield and plant N concentration at maturity, yet it did not improve the amount of N allocated to the grain [16]. Peltonen [11], on the basis of ear developmental stages in spring wheat cultivars, reported that foliar N spraying at a rate of 20 kg ha⁻¹, as an aqueous urea solution (144 gL⁻¹), both at the double-ridges stage and when the stigmatic branches of the carpel had been formed, increased the number of grains per ear and per m². Nitrogen added at pollination increased kernel weight and bread-making quality of spring wheat [11]. Salwau [15], observed that foliar application of 6% (w/v) urea at booting stage led to a higher wheat grain yield as compared with soil urea application. In a field trial conducted by Czuba [3], various combinations of foliar urea application and topdressing with equivalent rates of granular urea were evaluated, and it was found that foliar application resulted in a higher yield and greater N use efficiency than did the granular application. The best urea concentration ranged from 20% (w/v) at tillering to 5% (w/v) during ripening [3]. In a 2- year trial, Barraclough and Haynes [2] applied KNO₃ and urea as foliar application to winter wheat, observed that in the first year spraying with KNO₃ at the growth stages 39, 59 or 71 (see Zadoks *et al.*) [24] had no significant effect on the grain yield and/or grain N concentration. However, in the second year, the grain N concentration was higher while the grain yield decreased (more than 600 kg ha⁻¹). The yield response

to foliar urea spray has also been reported to vary among wheat genotypes [1,9]. Small or negative yield response to urea application have often been associated with excessive levels of leaf burn [21], which can be partially alleviated by reducing urea concentrations [7].

The objective of the present study was to determine the effects of rate and time of foliar urea application on the grain yield and yield components of two recently released and widely grown winter wheat cultivars ('Phalat' and 'Marvdasht') in Fars province of Iran.

MATERIALS AND METHODS

A field experiment was conducted at the Experimental Farm, College of Agriculture, Shiraz University, Shiraz, Iran, located at Badjgah (1810 m above the mean sea level with a longitude of 52° 32'E and latitude of 29° 36'N) during the 1998-1999 growing season. Some of the soil characteristics of the experimental site (fine, mixed, mesic, Calcixerollic Xerochrept) are given in Table 1. The meteorological data of the experimental site are shown in Fig.1. The design of the experiment was randomized complete block, arranged as split-plot factorial with three replicates. The treatments were composed of two winter wheat cultivars ('Phalat' and 'Marvdasht') as main plots and factorial levels of five rates and three times of foliar N application, as subplots. Single foliar application supplied 0, 8, 16, 24 and 32 kg ha⁻¹ N at booting (GS 45), anthesis (GS 65) and early milk (GS 73) stages. Uniform wheat seeds were hand sown in rows 15 cm apart giving 300 plants m⁻² density in plots of 2×8 m. Nitrogen was applied to each plot at the rate of 60 kg ha⁻¹ as urea just before planting and 60 kg ha⁻¹ at the flag leaf fully expanded stage, i.e. growth stage (GS 39) (see Zadoks *et al.*) [24]. The volume of spray was 800 L ha⁻¹ using a precision sprayer with constant pressure of 0.3 MPa. All of the sprays were applied at about 5 p.m. The control plots were

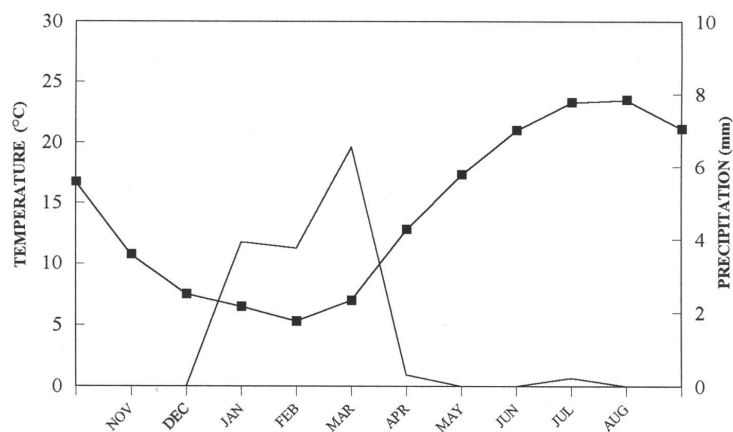


Figure 1. Average monthly temperature (■) and precipitation (-) of the experimental site at Badjgah during 1998-1999 growing season.

sprayed with water. Plots were irrigated when needed and hand weeded. Dry weights were determined after plant materials were oven-dried at 80°C for 48h. At maturity, (GS 92), the following characters were measured from 1 m² final harvest area of each plot:

- 1) Number of fertile ears m⁻²
- 2) Number of kernels ear⁻¹
- 3) Biological yield (g m⁻²); i.e. the above ground total dry matter of each plot sample.
- 4) Grain yield (g m⁻²)
- 5) Mean grain weight (mg)
- 6) Harvest index (%); i.e. the ratio of grain yield to total dry matter produced in each plot sample.

The collected data were subjected to analysis of variance using MSTATC (Version 1.42) software. Mean comparisons were made using the Duncan's new multiple range test (DNMRT).

RESULTS AND DISCUSSION

Foliar urea spraying of Marvdasht cultivar at all N levels significantly increased the grain yield over the control plots, however, in Phalat cultivar significant increase in grain yield was observed only by 16 kg N ha⁻¹ treatment (Table 2). Foliar urea feeding at 16 kg N ha⁻¹ increased significantly the grain yield by 113.6 g m⁻² (27%) in Phalat,

and at 8 kg N ha⁻¹, by 88 g m⁻² (19%) in Marvdasht cultivar as compared to control plots. Maximum grain yield was achieved by foliar application of 16 and 32 kg N ha⁻¹ for Phalat and Marvdasht cultivars, respectively (Table 2). The differences in grain yield response obtained in this experiment have also been reported by Altman *et al.* [1] and Grama *et al.* [9]. However, no clear reason for these differences have been stated. Pushman and Bingham [13], and Gooding *et al.* [8] indicated that yield improvement by foliar urea application have been relatively consistent over a range of cultivars. However, in the present investigation, Phalat cultivar did not respond to urea levels greater than 16 kg N ha⁻¹ (Table 2). Leaf burn, due to excessive amounts of urea spraying, which was noticed during the experimental period, have probably been the main reason for such a response in this cultivar.

The increase in grain yield with foliar urea application was associated with increased number of grains ear⁻¹ in both cultivars, however, the mean grain weight was not affected by foliar N feeding in either cultivars (Table 2). Similar results have been reported by Sadaphal and Das [14], and

**Table 2.** The main effects of levels of foliar N application as urea on yield and its components of two winter wheat cultivars.

Cultivars	Levels of N (kg/ha)	Grain yield (g m ⁻²)	Fertile ears (m ⁻²)	Harvest index (%)	Biological yield (g m ⁻²)	Grains ear ⁻¹	Mean grain Wt. (mg)
Phalat	0	412.3 c	550.0 bc	40.7 bc	1011 d	25.54 ab	39.47 a
	8	454.6 c	562.1 abc	41.5 bc	1096 cd	23.10 b	39.66 a
	16	525.9 b	596.5 a	42.5 bc	1237 ab	28.64 a	40.06 a
	24	450.1 c	534.9 c	41.1 bc	1095 cd	26.07 ab	40.06 a
	32	463.4 c	527.2 c	40.0 c	1159 bc	26.84 a	40.82 a
Marvdasht	0	459.5 c	573.1 ab	42.4 bc	1083 cd	22.69 b	39.20 a
	8	548.0 ab	598.3 a	44.8 ab	1224 ab	22.38 b	39.75 a
	16	590.6 a	601.8 a	44.8 ab	1317 a	27.54 a	40.42 a
	24	559.2 ab	584.7 ab	45.3 ab	1234 ab	28.26 a	40.59 a
	32	591.8 a	549.8 bc	46.9 a	1261 ab	29.09 a	40.88 a

Means followed by the same letter in each column are not significantly different at 5% level using DNMRT.

Spiertz and Ellen [19]. In a foliar N application experiment on spring wheat, Peltonen [11] found that grain number ear⁻¹ was increased when the number of initiated florets were maximum at developmental stage, DS 7 [23]. This was due to an increase in fertile florets per spikelet. The foliar urea spraying also improved the harvest index of Marvdasht cultivar significantly, i.e. from 42.4 percent at 0 N application to 46.9 percent at 32 kg N ha⁻¹. However, foliar N had no significant effect on Phalat cultivar. The increase in harvest index of Marvdasht cultivar was associated with increased number of grains ear⁻¹ (Table 2) which is in agreement with the findings of others [18,22]. Foliar feeding up to 16 kg N ha⁻¹ also increased the biological yield in both Phalat and Marvdasht cultivars, (Table 2). Turley and Ching [22], in a green-house experiment

also found that vegetative growth was increased by three weekly sprays of urea-ammonium nitrate on 12-week-old barley plants.

Timing of N application had a significant effect on the grain yield (Table 3). The early foliar application (i.e. at booting stage, GS 45, see Zadoks *et al.*) [24] gave a higher grain yield increase as compared to applications at flowering (GS 65) and early milk (GS 73) stages in both cultivars (Table 3). These results confirmed the findings of other researchers [2,6,16,20]. Although the harvest index for both cultivars was significantly affected by timing of N application, the effect of timing of N application on the number of grains ear⁻¹ as well as mean grain weights were negligible (Table 3). The harvest index at early foliar N feeding (i.e. at booting) was higher than that at later appli-

Table 3. The main effects of time of foliar N application as urea on grain yield and its components of two winter wheat cultivars.

Cultivars	Time of foliar urea application	Grain yield (g m ⁻²)	Fertile ears (m ⁻²)	Mean grain. wt (mg)	Biological yield (g m ⁻²)	Harvest index (%)	Grains ear ⁻¹
Phalat	Booting	503.8 bc	563.8 a	39.80 a	1169 bc	43.1 b	27.23 a
	Flowering	462.8 c	561.1 ab	40.23 a	1124 cd	41.2 bc	26.35 a
	Early milk	417.2 d	537.5 b	40.21 a	1067 d	39.1 c	24.55 a
Marvdasht	Booting	591.8 a	572.3 a	40.14 a	1253 a	47.2 a	27.31 a
	Flowering	532.1 b	582.3 a	40.17 a	1203 abc	44.2 b	26.09 a
	Early milk	525.7 b	588.2 a	40.18 a	1215 ab	43.2 b	24.57 a

Means followed by the same letter in each column are not significantly different at 5% level using DNMRT.

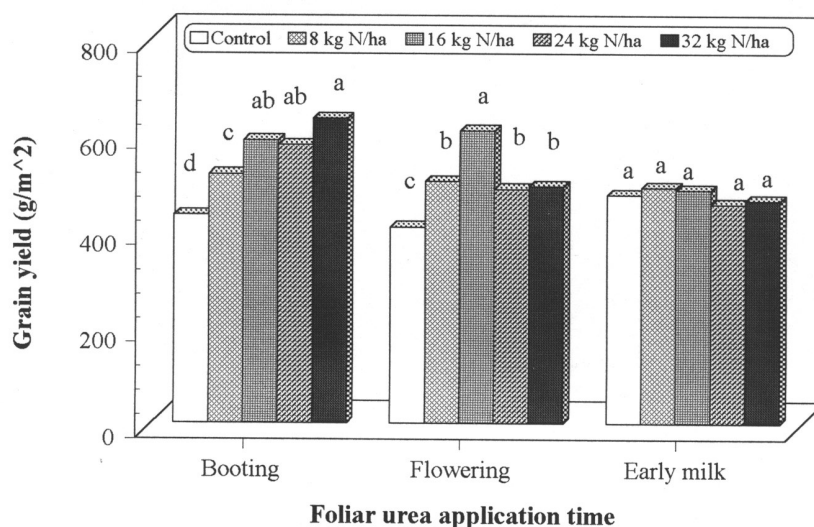


Figure 2. Interaction between different levels and time of N foliar application on the grain yield (Means of two cultivars over three replicates). Columns with similar letters, for each application time, are not significantly different at 5% probability level using (DNMRT).

cations in both cultivars (Table 3). Similar results have been reported by Spiertz and Ellen [19]. They found that increased grain number ear⁻¹ and mean grain weight were responsible for greater harvest index.

The interactive effect of rate and timing of foliar urea application on the grain yield is shown in Fig. 2. The highest grain yield was achieved with 32 kg ha⁻¹ foliar feeding at

booting stage while later applications were associated with lower grain yield. The interactions between rate and timing of urea foliar application on biological yield and harvest index are also shown, in Figs. 3 and 4 respectively. The earlier foliar application with higher urea rates resulted in a greater biological yield and harvest index. Smaller green area in which the spray was inter-

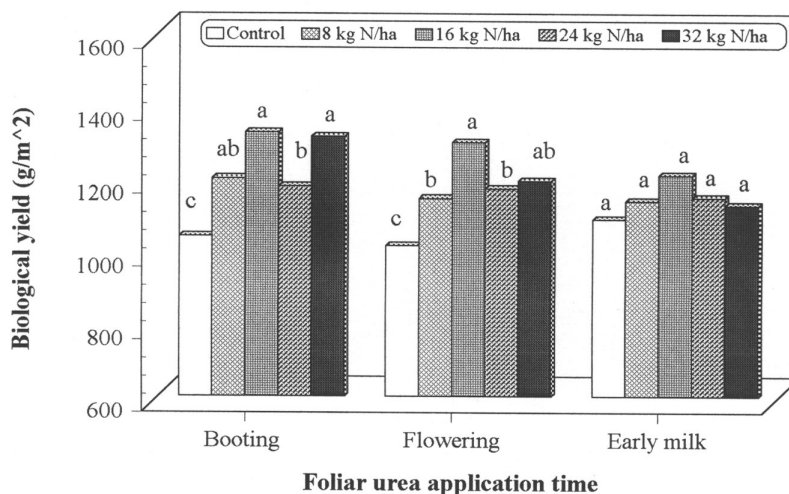


Figure 3. Interaction between different levels and time of N foliar application on the biological yield (Means of two cultivars over three replicates). Columns with similar letters, for each application time, are not significantly different at 5% probability level using (DNMRT).

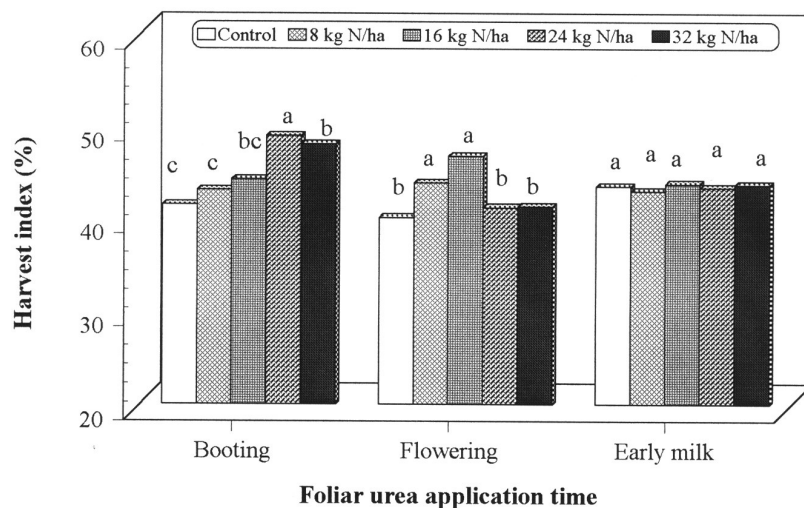


Figure 4. Interaction between different levels and time of N foliar application on the harvest index (Means of two cultivars over three replicates). Columns with similar letters, for each application time, are not significantly different at 5% probability level using (DNMRT).

cepted at later applications seemed to be a contributory factor to these interactions. In the present study, it was also found that late N applications had no significant effect on mean grain weight (Table 3). Indeed, the mean grain weight is the most stable component of the grain yield in wheat [5]. This indicated that under conditions similar to those in this experiment yield increase through an increase in mean grain weight could not be achieved by late N applications.

In summary, it was found that early N foliar feeding, i.e. application at booting stage, resulted in a grain yield increase in both cultivars. The yield increase was mainly due to increase in grain number with no significant change in mean grain weight. Cultivars differed in their response to foliar N feeding and Marvdasht was found to be more responsive than Phalat cultivar.

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REFERENCES

1. Altman, D.W., McCuiston, W.L., and Kostrad, W.E.1983. Grain Protein Percentage, Kernel Hardness and Grain Yield of Winter Wheat with Foliar Applied Urea. *Agron. J.*, **75**: 87-91.
2. Barraclough, P.B., and Haynes, J.1996. The Effect of Foliar Supplements of Potassium Nitrate and Urea on the Yield of Winter Wheat. *Fert. Res.*, **44**: 217-223.
3. Czuba, R. 1994. The Results of Foliar Nutrition of Field Crops. I. Responses of Plants to Foliar Nitrogen Application. *Field Crop Abst.*, **49**: 1303.
4. Dampney, P.M.R., and Salmon, S.1990. The Effect of Rate and Timing of Late Nitrogen Applications to Bread-making Wheats as Ammonium Nitrate or Foliar Urea-N, and the Effect of Foliar Sulphur Application. I. Effect on Yield, Grain Quality and Recovery of Nitrogen in Grain. *Asp. Appl. Biol.*, **25**: 229-241.
5. Darvinkel, A. 1979. Ear Size in Relation to Tiller Emergence and Crop Density. In. "*Crop Physiology and cereal breeding*". (Eds): Spiertz, J.H.J. and Kramer, T.H., Pudoc Press, Wageningen, pp. 10-15.
6. Finney, K.F., Meyer, J.W., Smith, F.W., and Fryer, H.C.1957. Effect of Foliar Spraying on Pawnee Wheat with Urea Solution on

- Yield, Protein Content, and Protein Quality. *Agron. J.*, **49**: 341-347.
7. Frank, W. 1967. Mechanisms of Foliar Penetration of Solutions. *Ann. Rev. Plant Physiol.*, **18**: 281-300.
 8. Gooding, M.J., Kettlewell, P.S., Davies, W.P., Hocking, T.J., and Salmon, S.E. 1987. Interactions Between Late-season Foliar Urea and Fungicide Applications on the Bread-making Quality of Winter Wheat. *Asp. Appl. Biol.*, **15**: 385-394.
 9. Grama, A., Porter, N.G., and Wright, D.C.S. 1987. Hexaploid Wild Emmer Wheat Derivatives Grown Under New Zealand Conditions II. Effect of Foliar Urea Sprays on Plant and Grain Nitrogen and Baking Quality. *N. Zealand J. Agric. Res.*, **30**: 45-51.
 10. Gray, R.C. 1977. Foliar Fertilization with Primary Nutrients During Reproductive Stage of Plant Growth. *Proc. Fert. Soc. London*. no. 164.
 11. Peltonen, J. 1992. Ear Developmental Stage Used for Timing Supplemental Nitrogen Application to Spring Wheat. *Crop Sci.*, **32**: 1029-1033.
 12. Powlson, D.S., Poulton, P.R., Penny, A., and Hewitt, M.V. 1987. Recovery of ^{15}N -labelled Urea Applied to the Foliage of Winter Wheat. *J. Sci. Food Agric.*, **41**: 195-203.
 13. Pushman, F.M., and Bingham, J. 1976. The Effects of a Granular Nitrogen Fertilizer and a Foliar Spray of Urea on the Yield and Bread-making Quality of ten Winter Wheats. *J. Agric. Sci. Camb.*, **87**: 281-292.
 14. Sadaphal, M.N., and Das, N.B. 1966. Effect of Spraying Urea on Winter Wheat, (*Triticum aestivum* L.). *Agron. J.*, **58**: 137-141.
 15. Salwau, M.I.M. 1994. Effect of Soil and Foliar Application of Nitrogen Levels on Yield and Yield Components of Wheat (*Triticum aestivum* L.). *Field Crop Abst.*, **49**: 2192.
 16. Sarandon, S.J., and Gianibelli, M.C. 1990. Effect of Foliar Urea Spraying and Nitrogen Application at Sowing upon Dry Matter and Nitrogen Distribution in Wheat (*Triticum aestivum* L.). *Agronomie.*, **10**: 183-189.
 17. Singh, R.P., and Seth, J. 1978. Nitrogen Uptake and Potential for Production of Dry Matter in Dwarf Wheat as Influenced by Soil and Foliar Application of Nitrogen. *Indian J. Agric. Sci.*, **48**: 342-346.
 18. Smith, J. J., Burn, M. R., and Bartlett, J. H. 1987. The Effect of Foliar Applied Nitrogen on the Quality of Winter Wheat. *Asp. Appl. Biol.*, **15**: 277-281.
 19. Spiertz, J.H.J., and Ellen, J. 1978. Effects of Nitrogen on Crop Development and Grain Growth of Winter Wheat in Relation to Assimilation and Utilization of Assimilates and Nutrients. *Neth. Agric. Sci.*, **26**: 210-231.
 20. Strong, W.M. 1982. Effect of Late Application of Nitrogen on the Yield and Protein Content of Wheat. *Aus. J. Exp. Agric. Anim. Husb.*, **22**: 54-61.
 21. Sylvester-Bradley, R., Dampney, P.M.R., and Murray, A.W.A. 1984. The Response of Winter Wheat to Nitrogen. In: "The Nitrogen Requirement of Cereals", ADAS/MAFF Reference Book, London. pp. 15 1-174.
 22. Turley, H.R., and Ching, T.M. 1986. Physiological Responses of Barley Leaves to Foliar Applied Urea-Ammonium Nitrate. *Crop Sci.*, **26**: 987-993.
 23. Waddington, S.R., Cartwright, P.M., and Wall, P.C. 1983. A Quantitative Scale of Spike Initial and Pistil Development in Barley and Wheat. *Ann. Bot.*, **51**: 119-130.
 24. Zadoks, J.C., Chang, T.T., and Konzak, C.F. 1974. A Decimal Code for the Growth Stages of Cereals. *Weed Res.*, **14**: 415-421.

عملکرد و اجزای عملکرد دانه دو رقم گندم (*Triticum aestivum* L.) در واکنش به میزان و زمان تغذیه برگ‌ی اوره

چکیده

یکی از روشهای تغذیه نیتروژن غلات دانه ای تغذیه برگ‌ی اوره می باشد. عملکرد و تمامی اجزای عملکرد گیاه ممکن است بوسیله تغذیه برگ‌ی اوره تحت تاثیر قرار گیرند. به منظور بررسی اثر میزان



و زمان تغذیه برگی اوره بر عملکرد و اجزای عملکرد دانه دو رقم گندم فلات و مرودشت، پژوهش حاضر در مزرعه تحقیقاتی دانشکده کشاورزی دانشگاه شیراز واقع در باجگاه (36° و 29° درجه شمالی و 52° درجه شرقی) در سال زراعی ۷۸-۷۷ اجرا گردید. در این پژوهش دو رقم گندم زمستانه فلات و مرودشت، پنج میزان تغذیه برگی اوره (صفر، ۸، ۱۶، ۲۴ و ۳۲ کیلوگرم در هکتار نیتروژن) در سه زمان پیش از گلدهی، گلدهی و پس از گلدهی در یک آزمایش اسپلیت پلات- فاکتوریل در قالب طرح بلوکهای کامل تصادفی و در سه تکرار مورد مطالعه قرار گرفت. نتایج به دست آمده نشان داد که محلول پاشی اوره به میزان ۸ کیلوگرم نیتروژن در هکتار عملکرد دانه در رقم مرودشت را به طور معنی دار (۱۹٪) افزایش داد، حال آنکه در رقم فلات با کاربرد ۱۶ کیلوگرم نیتروژن در هکتار عملکرد دانه افزایش معنی دار (۲۷٪) نشان داد. افزایش عملکرد دانه در هر دو رقم عمدتاً نتیجه افزایش تعداد دانه در سنبله بود، به طوری که تعداد سنبله در متر مربع و متوسط وزن هر دانه تحت تاثیر میزان تغذیه برگی اوره قرار نگرفت، لیکن تغذیه برگی باعث افزایش شاخص برداشت و عملکرد بیولوژیکی گردید. محلول پاشی پیش از گلدهی عملکرد دانه زیادتری در مقایسه با مصرف دیرتر اوره به دست داد. همچنین محلول پاشی زودتر اوره به میزان ۳۲ کیلوگرم نیتروژن در هکتار، شاخص برداشت را از ۴۲/۴٪ به ۴۶/۹٪ در رقم مرودشت افزایش داد. نتایج این پژوهش همچنین حاکی از آن بود که تاخیر در زمان مصرف اوره، به صورت محلول پاشی، ممکن است کارایی مصرف نیتروژن را کاهش دهد.