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EFFECT OF UREA FOLIAR FEEDING ON GRAIN PROTEIN CONTENT AND QUALITY IN TWO WINTER WHEAT CULTIVARS

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ABSTRACT

In a field experiment, the effect of rate and time of foliar urea application on protein content and quality in two cultivars of winter wheat, 'Falat' and 'Marvdasht', was studied. A split-plot arrangement of treatments in a randomized complete block design was used with cultivars as the main plots and factorial levels of five urea foliar application rates (0, 8, 16, 24 and 32 kg N ha^{-1}) and three stages of application (booting, anthesis and early-milk), as sub-plots. The results showed that each 8 kg ha^{-1} increment in N applied as urea was associated with a 0.6% increase in grain protein in both cultivars. Both grain yield and protein percentage were increased resulting in higher protein yield. Several measured protein quality criteria (farinograph water absorption, wet gluten and sodium dodecyl sulphate (SDS)-sedimentation) were improved by foliar N application. Farinograph absorption was positively, but not strongly, correlaterd to the grain protein in both cultivars. Wet gluten and SDS sedimentation volume were not related to the grain protein of either cultivar. These results suggested that foliar N feeding at appropriate time and rate could be employed, with no leaf damage or risk of lodging, to enhance both grain protein and its quality.

Key words : Wheat, Quality, Foliar N feeding.

1. Former Graduate Student and Associate Professor, respectively.

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تأثیر تغذیه برگی اوره بر میزان و کیفیت پروتئین دانه های دو رقم گندم

علیرضا برجیان و یحیی امام

به ترتیب دانشجوی سابق کارشناسی ارشد و دانشیار بخش زراعت و اصلاح نباتات دانشکدهٔ کشاورزی دانشگاه شیراز، شیراز، جمهوری اسلامی ایران.

چکیده

در یک آزمایش مزرعه‌ای، تأثیر میزان و زمان تغذیهٔ برگی اوره بر میزان و کیفیت پروتئین دانه های دو رقم گندم زمستانه 'فلات' و 'مرودشت' بررسی شد. آزمایش، به صورت کرت های خرد شده در قالب طرح بلوک های کامل تصادفی بود که در آن دو رقم گندم زمستانه، به عنوان کرت اصلی و پنج سطح تغذیهٔ برگی (۰، ۸، ۱۶، ۲۴ و ۳۲ کیلوگرم نیتروژن در هکتار) و سه زمان مصرف نیتروژن (غلاف رفتن، گلدهی و آغاز شیری شدن دانه) به عنوان کرت فرعی قرار داشتند، اجرا گردید. نتایج نشان داد که به ازای هر ۸ کیلوگرم نیتروژن بکار رفته در تغذیهٔ برگی پروتئین دانه هر دو رقم گندم۶ /۰ درصد افزایش یافت. افزایش عملکرد پروتئین دانه به دنبال تغذیهٔ برگی نیتروژن ناشی از افزایش عملکرد دانه و افزایش درصد پروتئین دانه بود. در نتیجه تغذیه برگی بوته ها، شاخص های کیفیت دانه (جذب آب، گلوتن تر و رسوب SDS) بهبود یافتند. در هر دو رقم گندم، جذب آب همبستگی مثبت ولی کوچکی با پروتئین دانه داشت. بین گلوتن تر و حجم رسوب SDS با میزان

پروتئین دانه رابطهٔ مشخصی در هیچیک از ارقام به دست نیامد. این نتایج نشان از امکان کـاربرد بـه موقع و به اندازه نیتروژن بصورت تغذیه برگی ، بدون این که باعث برگ سوزی یا خوابیدگـی شـود، با هدف افزایش کمیت و کیفیت پروتئین دانه گندم است.

INTRODUCTION

Wheat grain protein content is dependent on environmental factors such as temperature, light intensity and soil moisture availability (22) and can also be influenced by tillage (21) and previous crop (32). The grain protein content can be increased when a substantial part of the total crop N pool was still available, or could be supplemented, later in the growing season (30).

Wheat grain protein content can be used as an indicator of N sufficiency for yield (12) since luxurious consumption of N in excess of grain yield requirements can produce higher grain protein content (5, 8). Some of the differences in grain protein content can be related to N uptake efficiency or greater fertilizer usage potential among varieties (3).

The harvest index has increased due to reduction of stem length through selections (3). According to Kramer (16), lower straw production presents a smaller vegetative mass and a smaller N pool from which protein could be redistributed to the grain at grain filling. However, the strategy of increasing N concentration could be achieved through increasing crop N pool via high levels of N application (4).

The remobilization of vegetative N during grain fill in wheat markedly contributes to the final grain N content. Van Sanford and Mackown (27) found that the proportion of total above ground N accumulated by the spike ranged from 51 to 91% among cultivars. An analysis of cultivar differences indicated that the cultivar variation in final spike N could be associated with variation in N uptake. They also reported that the higher post-anthesis N uptake was associated with the lower N utilization efficiency (spike weight / total plant N), higher grain N concentration, and lower grain yields.

Increasing the nitrogen content of wheat grain usually improves loaf volume (9). However, Pushman and Bingham (19) despite an average increase in protein content from 11.98% to 12.96%, following an application of urea at anthesis, found no increase in loaf volume. In a Canadian experiment (25), foliar urea applications gave a large increase in crude protein content (from 12.1% to >16%), with ammonium nitrate applications to the soil, however, the dough strength and the quality of loaf crumb texture were reduced. Finney *et al.* (9) suggested that the reason why some multiple urea spray gave large increases in protein content (e.g., from 10.8% to 21%) but did not give correspondingly large increases in loaf volume was due to incomplete synthesis of the gluten fraction of the flour.

Winkler and Schon (29) reported that late N application at ear emergence of barley plant increased total plant N percentage, whereas N fertilization in seedling growth stage led to increases in all amino acids for making proteins. They concluded that increasing both protein and its quality were not achievable.

Salmon *et al.* (23) by adding foliar urea ranging from 0 to 180 kg ha^{-1} applied at milk-ripe stage or granular ammonium nitrate at GS 32 (31) found that additional N, irrespective of the application method, increased the sodium dodecyl sulphate (SDS) sedimentation volume, but flour SDS response frequently decreased at levels higher than 120 kg N. Also, they obtained the highest increase of protein percent at GS 39 (i.e. Flag leaf fully expanded stage) and 30-40 days later. In two field experiments conducted by Gianibelli and Sarandon (11), two wheat cultivars were sprayed with 20 kg N ha^{-1} as urea at anthesis, 7 and 14 days after anthesis, and at tillering, anthesis and 21 days after anthesis.They found that N application increased grain protein content irrespective of application date. Gluten content increased in both cultivars by N application between anthesis and 14 days after anthesis, while delayed N application increased gluten content only in one cultivar. The Zeleny sedimentation value increased by N application at anthesis and later. Flour strength, being correlated with gluten content, was modified by N application. Tenacity increased by spraying N at anthesis and 21 days after anthesis. N application at anthesis also increased loaf volume.

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

MATERIALS AND METHODS

A field experiment was conducted at the Experimental Farm of College of Agriculture, Shiraz University, Shiraz, Iran, located at Badjgah (29° 36′ N and 52° 32′ E) during the 1998-1999 growing season. The soil of the experimental site was fine, mixed, mesic, Calcixerollic Xerochrept. A split-plot arrangement of treatments in a randomized complete block design with three replicates was used. The treatments were composed of two winter wheat cultivars ('Falat' and 'Marvdasht'), as main-plots and factorial levels of five rates and three times of N foliar application as sub-plots. 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 as urea and phosphorus as super-triple phosphate were applied to each plot at the rate of 60 kg N and 60 kg P ha^{-1} just before planting and again 60 kg N ha^{-1} at the end of tillering. The volume of spray was 800 l ha^{-1} using a precision sprayer with constant pressure of 3 bar.

The control plots were sprayed with water. During spraying the corresponding plot was surrounded by plastic wall to avoid contamination of adjacent plots. Plots were irrigated as required and regularly hand-weeded. No leaf damage or lodging was observed.

Grain protein concentration was measured using micro- Kjeldahl analysis. The protein yield per square meter was calculated from grain yield and protein concentration.

Sub-samples, taken from each plot, were mixed thoroughly for quality analysis, and then milled with a Brabender Quadrumat Senior Mill (13). Farinograph was done by a Brabender Farinograph / Resistograph with small

mixing bowl (50 g flour) and flour water absorption and dough stability were determined.

The wet gluten of the flour samples was determined by a Glutamatic 2100 and described as percent (14). Gluten quality was evaluated with the sodium dodecyl sulphate (SDS) sedimentation test based on Quick and Donnelly (20). The collected data for each character were subjected to analysis of variance and the means were compared using Duncan's new multiple range test.

RESULTS AND DISCUSSION

Grain Protein Percentage

Foliar urea application increased grain protein percent of both cultivars significantly (Fig.1) so that each additional 8 kg N ha^{-1} produced a mean increase of 0.6% in grain protein. There was a significant interaction between rate and time of foliar urea application on grain protein percent. Although timing of foliar urea application had no marked effect on the size of response to increased grain protein content, application of 32 kg N ha^{-1} at flowering resulted in the highest grain protein percent (12.4%), (Fig. 2). These results may indicate that even with wheat yields in excess of 5 t ha^{-1} (the highest oven-dried mean yield achieved in this trial was 5584 kg ha^{-1}), it is possible to increase grain protein levels by using foliar N application. Results of previous foliar ^{15}N feeding experiments also indicated rapid N uptake and effective recovery of N in the grain (e.g., 2, 7). The increased grain protein of sprayed wheat plants in this study may, therefore, be attributed to a direct consequence of foliar N feeding, which probably elevated substrate and/or machinery for protein synthesis. Turley and Ching (26) suggested that foliarly applied urea-ammonium nitrate can be converted to amino acids in the wheat leaves and green seed parts at the expense of sugars that are incorporated into C backbones of amino acids and catabolized as respiratory energy for the incorporation. The amino acids are then transported to the developing endosperm where they are used in the production of additional protein. The lower grain protein responses observed

in this trial by application of 32 kg N ha^{-1} at booting and early milk stages (Fig. 2), may be due to lower N uptake or reduced N translocation. Similar results were also reported by Spirtz and Ellen (24) and Whitfield *et al.* (28).

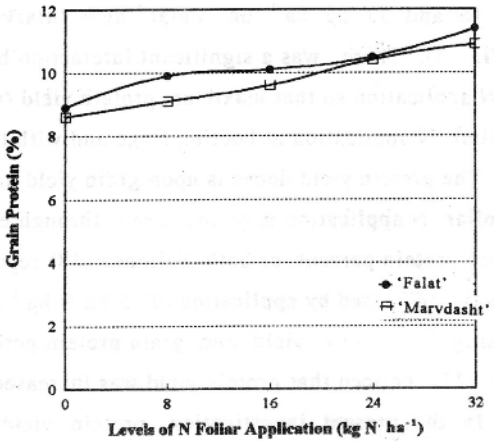

Fig. 1. The effect of different levels of urea-N foliar application on the grain protein percent of two winter wheat cultivars ('Falat' and 'Marvdasht').

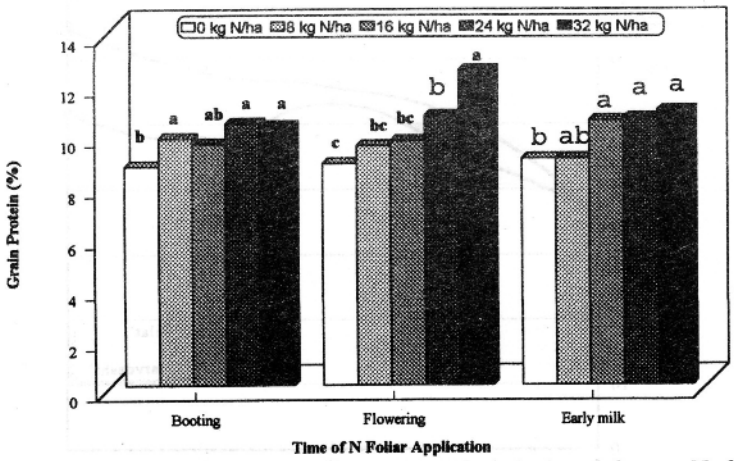

Fig. 2. Interaction between different levels and time of urea-N foliar application on the grain protein percent. Columns with the same letter at each application time are not significantly different at 0.05 level of probability.

Protein Yield

The rate of foliar urea application significantly increased protein yield of both cultivars (Fig. 3). Maximum protein yield was achieved by foliar application of 16 and 32 kg ha^{-1} on 'Falat' and 'Marvdasht' cultivars, respectively (Fig. 3). There was a significant interaction between rate and time of foliar N application so that maximum protein yield (65.1 g m^{-2}) was achieved by foliar N application at booting stage and with the rate of 32 kg N ha^{-1} (Fig. 4). The protein yield depends upon grain yield and grain protein content, and foliar N application may increase it through enhancing better grain yield, grain protein percent, or both. Peltonen (18) reported that wheat protein yield was increased by application of 15 kg N ha^{-1} at booting stage through increasing both grain yield and grain protein percent. In another study, Peltonen (17) noticed that protein yield was increased only via grain yield increase. In the present investigation, protein yield was increaesed through both increased grain yield (data not shown) and grain protein percent.

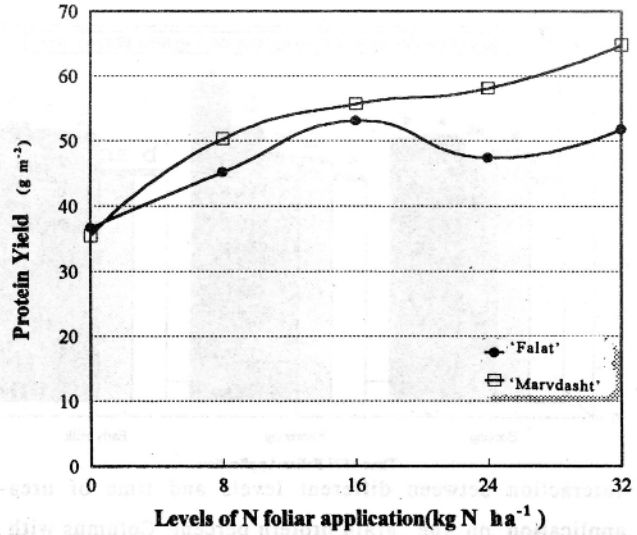

Fig. 3. The effect of different levels of Urea-N foliar application on the protein yield of two winter wheat cultivars ('Falat' and 'Marvdasht').

Quality Parameters

Differences in grain protein by foliar spray of urea were evaluated to determine if they affected quality parameters. Urea foliar application significantly affected farinograph water absorption percentage (Fig. 5).

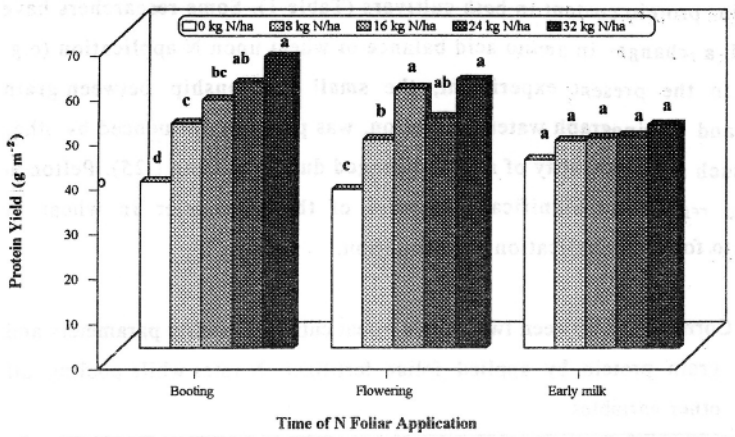

Fig. 4. Interaction between different levels and time of Urea-N foliar application on the protein yield. Columns with the same letter at each application time are not significantly different at 0.05 level of probability.

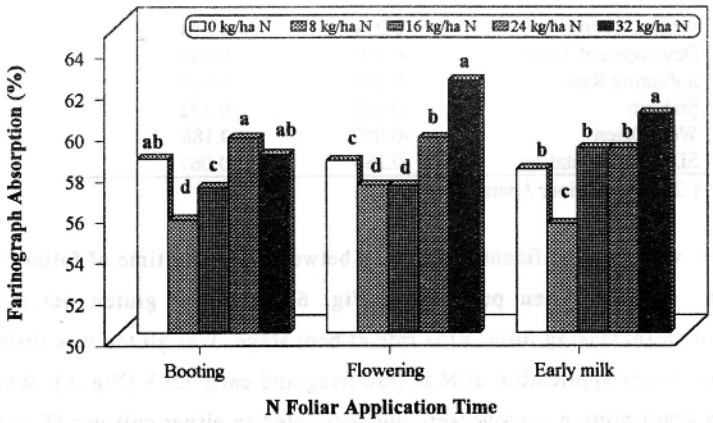

Fig. 5. Interaction between different levels and time of urea-N foliar application on the farinograph water absorption. Columns with the same letters in each N foliar application time are not significantly different at 0.05 level of probability.

Maximum value of this parameter was obtained when 32 kg N ha^{-1} was applied at flowering (Fig. 5). With pooling treatments other than cultivars, farinograph water absorption was positively, but not strongly, correlated to the grain protein content in both cultivars (Table 1). Some researchers have observed a change in amino acid balance of wheat upon N application (e.g. 1, 23). In the present experiment, the small relationship between grain protein and farinograph water absorption, was probably influenced by other factors such as the quantity of starch damaged during milling (25). Peltonen (17) also reported a significant increase of this parameter in wheat in response to foliar N application at pollination.

Table 1. Correlations between two winter wheat cultivars quality parameters and grain protein by applied foliar fertilizer N rates while pooling all other variables.

	Cultivar	
	Marvdasht	Falat
Parameter	Grain Protein	
	..... r	
Water Absorption †	0.259	0.354
Development Time	-0.292	-0.440
Softening Rate	0.335	0.045
Stability	-0.005	-0.382
Wet Gluten	-0.057	0.180
SDS-Sedimentation	0.284	-0.067

† 24 Observations / parameter.

There was a significant interaction between rate and time of foliar N application on wet gluten percentage (Fig. 6). The wet gluten percent increased with increasing foliar urea rate at boot stage. Wet gluten was little affected by foliar application of N at flowering and early milk (Fig. 6). Wet gluten and grain protein content were not correlated in either cultivar (Table 1). The increase in wet gluten content at boot, observed in the present research, and lack of correlation across growth stages with grain protein content may be due to the effect of N fertilizer on the proportion of proteins (23).

SDS sedimention also was affected by the rate of urea foliar application and responsed positively to foliar urea application, particularly at the early milk stage (Fig. 7). The grain protein was weakly correlated with SDS sedimentation only in Marvdasht cultivar (Table 1).

The SDS-sedimentation test which evaluates gluten quality is positively related to bread making quality (20). In the present study, increase in SDS-sedimentation volume by foliar N application (Fig. 7), and a weak relationship to the grain protein may also be related to the proteins within the sediment. This also may be a reason for increasing dough softening rate and dough development time and reduced dough resistance upon application of foliar urea. The weak correlation between dough softening rate and grain protein, observed in the present study (Table 1), may be dependent upon cultivar (15). These observations may suggest that foliar urea application has probably influenced other factors such as gluten fractions or high molecular weight (HMW) glutenin subunits (10) and /or change in N/S ratio (6), though it needs further research to be verified.

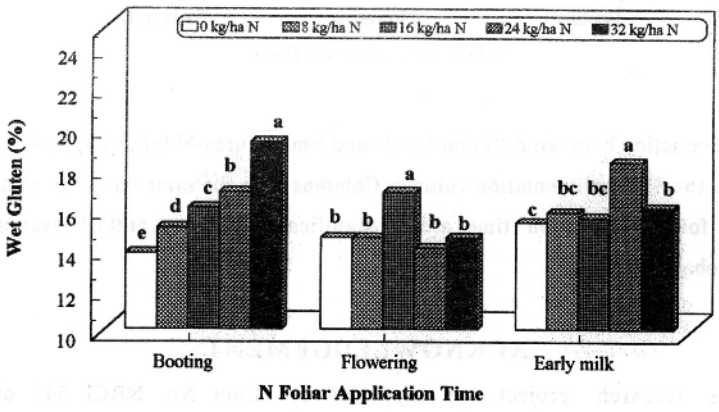

Fig. 6. Interaction between different levels and time of urea-N foliar application on the wet gluten. Columns with the same letters in each N foliar application time, are not significantly different at 0.05 level of probability.

In summary, foliar N feeding enhanced wheat grain protein and quality of both cultivars, and it was not associated with any leaf damage or lodging. Further research may shed more light on the effect of nitrogen supply on glutenin subunits and amino acid levels. Such research under wet and dry conditions and with or without sulphur supply would be important in variety selections for bread-making quality.

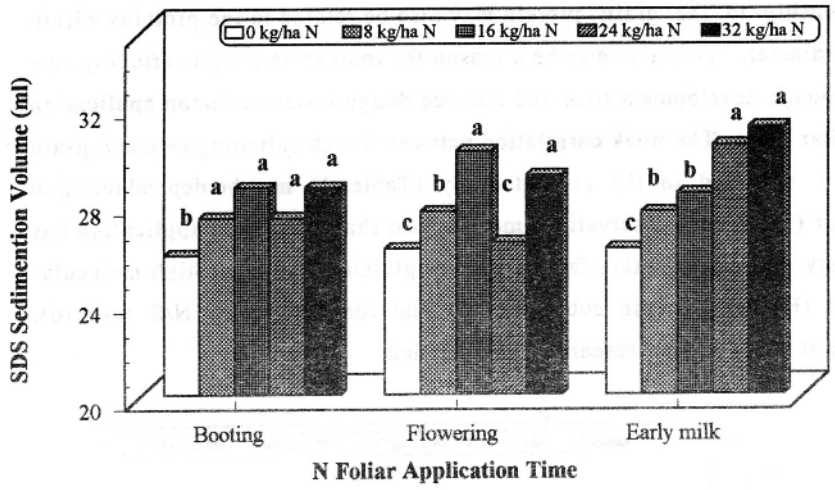

Fig. 7. Interaction between different levels and time of urea-N foliar application on the SDS sedimentation volume. Columns with the same letters in each N foliar application time, are not significantly different at 0.05 level of probability.

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