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Influence on Grain Yield and Grain Protein Content of Late-Season Nitrogen Application in Triticale

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Abstract: The study was carried out with the aim to determination the effects of late-season foliar N application on grain yield and protein content of Triticale. The research was conducted in arid land of Lakes region in Turkey during 2006-2008 growing seasons. The experiment was set up as randomized complete block design with a split-plot design with 3 replications. Triticale cultivars were main plots, the nitrogen were subplots split within main plots. In the study, winter/alternative Triticale cultivars (Tacettinbey, Tatlicak-97 and Karma-2000) were used. Nitrogen was applied as conventional (2 equal amounts at the time of seed sowing and tillering stage) and late-season foliar N application (1/3 of was applied during sowing, 1/3 at the tillering stage and the rest was applied to foliar at postpollination growth stage). In the study, effects of late-season foliar N application on grain yield and protein content of triticale were observed. Grain yield and protein content of triticale in both years of the study were significantly affected by N application timing. The results showed that the grain yield and grain protein content were higher in late-season foliar N application than conventional N application in both years of the study. Among the cultivars, the highest grain yield and protein content was obtained from Tatlicak-97 (2720 kg ha^{-1}) and Karma-2000 (13.1%) cultivars, respectively. The highest grain yield was determined from Tatlicak cultivar x late-season N interaction (2646, 2987 and 2815 kg ha^{-1}, respectively) in both years and average of years. The highest protein content was determined from Karma-2000 cultivar x late-season N interaction (13.8, 13.9 and 13.9%, respectively) in both years and average of years. Between grain yield and protein content was determined significant ($p \leq 0.01$) and positive connection (r^2 = 0.451).

Key words: Triticale, grain yield, grain protein, nitrogen

INTRODUCTION

Triticale (*xTriticosecale* Wittmack), a species resulting from the intergenetic crossing of wheat and rye, has the potential to introduce valuable economic and environmental benefits to grain production systems. Triticale is for use as a feed grain because it has proven to be a good source of protein, amino acids and B vitamins. Protein content and amino acid balance are in the range of wheat and rye in similar production environments (Varughese *et al*., 1996) and it has greater lysine content than corn. The higher lysine content gives triticale an average of 6% greater feed value than corn (Bruckner *et al*., 1998). The response of crop yield and protein to N applications depends on the balance between crop yield potential and N supply. Therefore, any factors, which influence the yield potential of the crop or the amount of N supplied to the crop through the growing season will influence the yield and protein content of the crop. To optimize grain yield and protein content the N supply must be matched to the yield potential of the crop. Therefore, rates of application should consider the amount of N supplied by the soil, the available moisture and the target yield. Low yielding cultivars will usually have a lower N requirement for optimal yield, so protein content will increase at lower N levels. Cultivars with high yield potential generally require higher rates of N fertilizer to optimize both yield and protein content (Gauer *et al*., 1992).

In terms of quality, triticale grain has less gluten than wheat, making it undesirable for bread making. Acceptable quality has been achieved by blending up to 50% triticale with wheat. In terms of protein quality, triticale generally has higher percentages of 2 essential amino acids, lysine and threonine. Animal-based trials have shown protein digestibility and feeding values similar to wheat. Triticale generally has higher forage yields but lower quality than wheat. It has similar crude protein values (20-25%) as wheat when grazed in the fall and spring, thus, making it better suited as pasture than for hay or silage (Shroyer *et al*., 1996).

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Nitrogen is the nutrient most commonly limiting to crop production in the arable. As N comprises about 16% of protein, N is also the nutrient with the greatest effect on protein content. Excess applications of N are not economically efficient and can reduce crop productivity and create environmental problems, while deficiencies in N supply can reduce both crop yield and protein content. To produce a high-yielding, high quality crops, the N supply must be balanced to the yield potential of the crop. Plant-available N is provided by mineralization of organic matter from summer fallowing, by release of N from high N residues or amendments such as legumes or manures, by accumulation of residual N in the soil, or through fertilizer application. If N in the soil is deficient, application of N fertilizer can increase both grain yield and protein content (Alkier *et al*., 1972).

Nitrogen is the major nutrient that influences triticale grain yield and protein content. Synthesis of protein in wheat grains depends on uptake of soil N before flowering, continual uptake during the grain filling and remobilization of stored vegetative N before flowering (Van Sanford and Mac Kown, 1987). Several studies have explored the timing and methods of N application in wheat elsewhere. Smith *et al.* (1991) observed positive increases in grain protein content with foliar N application and greater increase in grain protein content was obtained when the application was made close to flowering. Woolfolk *et al.* (2002) concluded that late season foliar N applications before or immediately after flowering may significantly enhance grain protein content in winter wheat. Langer and Liew (1973) reported that percentage grain N in wheat was increased with lateness of N application. Mi *et al.* (2000) investigated the effect of postanthesis N application to N-uptake and grain protein content. They found that additional N application during flowering could increase postanthesis N uptake and grain protein content but the degree of increase differed with cultivars. Their results were consistent with those of Van Sanford and Mac Kown (1987) and Spiertz and De Vos (1983), who found that crops with higher yield potential, may require additional N after anthesis to increase grain protein content. Bly and Woodward (2003) observed that post-pollination N application gave the highest grain protein content. Similarly, several other researchers including Powlson *et al.* (1989), Wuest and Cassman (1992), Ayoub *et al.* (1994) and Woolfolk *et al.* (2002) concluded that fertilizer N application near flowering is effective to increase post-flowering N uptake, grain yield and grain protein content. On the other hand, some other studies have reported that additional N applied postanthesis increased N uptake but did not increase grain protein content (Van Sanford and MacKown, 1987; Heitholt *et al*., 1990; Ehdaie and Waines, 2001). The objective of this study, was to determine the effects of late-season foliar nitrogen application on the grain yield and grain protein content of Triticale cultivars.

MATERIALS AND METHODS

The experiment was conducted at Lakes region, Isparta, in Turkey during 2006-07 and 2007-08 groving seasons. Experiment was set up as randomized complete block design with split plot arrangement with 3 replications. Triticale cultivars were main plots, the nitrogen were subplots split within main plots. In the study, winter/alternative Triticale cultivars (Tacettinbey, Tatlicak-97 and Karma-2000) were used. Seeds were sown with 15×5 cm row spaces using a parcel sowing machine. The net plot size was 1.2×8 m. Soil from a depth of 30 cm was sampled before the start of the experiment and subjected to physicochemical analysis. Sowing was made at October (autumn) in both years. Nitrogen rate was applied as 80 kg ha^{-1} in the form of ammonium nitrate (NH_4NO_3; 33.5%N). Nitrogen was applied as conventional (2 equal amounts at the time of seed sowing and tillering stage) and late-season foliar N application (1/3 of was applied during sowing, one-third at the tillering stage and the rest was applied to foliar at postpollination growth stage) (Zadoks *et al*., 1974). P_2O_5 (50 kg ha^{-1}) was applied once with sowing.

Characters of cultivars

Tacettinbey: The variety is alternative, with 1000 grain weight equals to 35-45 g and resistant to lodging, arid, disease, harmful and could be used for feeding and silage.

Tatlicak-97: The variety is wintery, with 1000 grain weight equals to 33-42 g and resistant to lodging, arid, cold, disease, harmful and could be used for feeding, blending flour and silage.

Karma-2000: The variety is brown seeded, wintery, with 1000 grain weight equals to 35-40 g and resistant to lodging, arid, cold, stres condition, disease, harmful and could be used for feeding and silage.

All cultural practices were kept regular and uniform for all treatments. In the study, grain yield and grain protein content were determined. Grain yield and grain protein content were determined in the following ways:

Grain yield was calculated as change from parcel grain yield to hectare. Grain nitrogen content was analyzed using a micro-Kjeldahl method (Simonne *et al*., 1996). Grain protein content was calculated from the N % content in grain multiplied by a conversion factor of 6.25.

Table 1: Climatic data of the region (2006-2008 growing seasons)

Parameters	Years	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Total/mean
Mean temperature (°C)	2006/07	13.4	6.1	2.2	1.1	3.1	7.1	9.5	17.5	21.6	9.1
	2007/08	14.4	7.4	2.7	-1.2	0.9	8.4	11.5	14.4	20.9	8.8
	Long term	12.0	7.5	3.0	2.5	5.1	9.3	10.8	15.6	20.1	9.5
Precipitation (mm)	2006/07	140.7	91.8	0.0	3.2	7.4	25.8	22.3	24.6	4.8	351.3
	2007/08	30.7	79.8	97.2	88.6	41.9	51.4	49.2	32.2	25.6	496.6
	Long term	28.9	76.9	98.0	46.9	28.0	42.9	56.6	50.8	24.4	453.4

Regional meteorology station, Isparta

Table 2: Physical and chemical contents of experimental area

Structure	Clay (%)	Silt (%)	Sand (%)	pH 1:1	EC 10^6 (dS m^{-1})	$CaCO_3$ (Lime)	Organic matter (g kg^{-1})	Available P (mg kg^{-1})	Nitrogen (%)
Loamy	23.1	33.9	43.0	8.1	400	255	13.4	199	0.14

Analysis of soil sample was made in the SDU Faculty of Agriculture

All the data were analyzed with Analysis of Variance (ANOVA) using SPSS Statistical Package Program. Means were compared using the Least Significant Difference (LSD) test.

Climatic data of the experimental area: Climatic data for crop growing seasons are shown in Table 1. Isparta has territorial climate (cold winters and dry hot summers) with an annual mean rainfall of 500 mm. The long-term average temperature from October to June is 9.5 EC. Precipitation is 453.4 mm for the same period. The vegetative periods (from October to June) in 2006-07 and 2007-08 had average temperatures of 9.1 and 8.8 EC, total precipitation of 351.3 and 496.6 mm, respectively.

Soil structure: Soil in a depth of 60 cm was sampled before the start of the experiment and subjected to physicochemical analysis. The experimental soil was low in nitrogen (0.14 N%) and phosphorus (199 mg kg^{-1} P_2O_5) and had alchalin (pH: 8.1) and loamy contents (Table 2). The data given in Table 2 indicated that there were other soil contents concerning experimental area.

RESULTS AND DISCUSSION

Analysis of variance of data regarding influence of late-season foliar nitrogen applications on grain yield and grain protein content of triticale are shown in Table 3. Means were compared using the Least Significant Difference (LSD) test. Grain yield was significantly influenced by year, cultivar, N application timing and the cultivar × N application timing interaction (Table 3). Grain protein content was significantly influenced by cultivar, N application timing and the cultivar × N application timing interaction (Table 3).

The mean grain yield of triticale was significantly influenced by year, but no statistically significant differences were found for grain protein content. Grain yield in second year (2810 kg ha^{-1}) was higher than fist year (2492 kg ha^{-1}) (Table 4). The mean grain protein content was 12.7% in 1st year and 12.8% in 2nd year (Table 5). Growing period rain in the 2nd year of the study was higher than 1st year (Table 1). Moisture supply may impact on crop yield, protein content and the capacity for plant utilization of available N (Gauer *et al*., 1992).

Triticale cultivars had significant effect, $p \leq 0.05$, 0.01, on grain yield in both years and average of years. The data given in Table 4 indicated that there was a significant difference on grain yield of Triticale cultivars in between years. In the both years and average of years, the highest grain yield was obtained from Tatlicak-97 cultivar (2548, 2893 and 2720 kg ha^{-1}, respectively) compare with other Triticale cultivars. The lowest grain yield was obtained from Tacettinbey cultivar (2448, 2695 and 2607 kg ha^{-1}, respectively) (Fig. 1). It is thought that differences in grain yield among cultivars result from genetic structures of variety, ecological factors and agricultural practices (Feil, 1992). All the Triticale cultivars and late-season N applications, the higher grain yield was obtained in 2nd year than 1st year. Differences in grain yield between years result from growing period rain in the 2nd year of the study was higher than 1st year. Moisture supply may impact on crop yield potential and N utilization. With low moisture, N fertilization will have minor effects on crop yield, since yield is more limited by moisture than by N supply. Different cultivars may also, differ in their yield and protein response to N application (Gauer *et al*., 1992). Low yielding cultivars will usually have a lower N requirement for optimal yield, so protein content will increase at lower N levels. Cultivars with high yield potential generally require higher rates of N fertilizer to optimize both yield and protein content.

Nitrogen application timing in Triticale had significant effect, $p \leq 0.01$, on grain yield in both years and average of years. The data given in Table 4 indicated that there was a significant difference on grain yield with N application timing in both years. When, late-season foliar nitrogen application used, triticale grain yield were significantly increased. During the 1st and 2nd years and the means of 2 years, the higher grain yield was obtained from

Table 3: Analysis of variance for effects of year, cultivar and late-season foliar nitrogen applications on grain yield and grain protein content of triticale

	Grain yield (kg ha^{-1})			Protein (%)		
Source of variation	1 year	2 year	Means of years	1 year	2 year	Means of years
Year (Y)	-	-	**	-	-	ns
Cultivar (C)	*	*	**	**	*	**
N applications timing (N)	**	**	**	**	**	**
C×N	*	**	*	*	**	**
Y×C	-	-	ns	-	-	ns
Y×N	-	-	ns	-	-	ns
Y×C×N	-	-	ns	-	-	ns

*,**Significant at 0.05 and 0.01 probability levels, respectively, ns: non signification

Table 4: Effect of nitrogen application time on grain yield (kg ha^{-1}) in the triticale

N applications /cultivars	2006-07			2007-08			Average of years		
	Conventional N	Late-season N	Average	Conventional N	Late-season N	Average	Conventional N	Late-season N	Average
Tacettinbey	2360	2537	2448B	2680	2853	2767B	2535	2695	2607B
Tatlicak-97	2450	2646	2548A	2800	2987	2893A	2620	2815	2720A
Karma-2000	2397	2547	2472B	2680	2863	2772B	2537	2705	2622B
Mean	2402B	2577A	2492B	2720B	2901A	281.0A	2564B	2738A	
	$Lsd_{variety: 65.15}$, $Lsd_{N: 75.6}$ $Lsd_{VarietyXN: 92.1}$			$Lsd_{variety:96.45}$, $Lsd_{N:112.0}$ $Lsd_{VarietyXN: 136.4}$			$Lsd_{variety:57.45}$, $Lsd_{N:162.4}$, $Lsd_{varietyXN: 79.2}$ $Lsd_{Year: 62.49}$		
Cv	2.03			2.67			2.5		

Table 5: Effect of nitrogen application time on protein content (%) in the triticale

N applications /cultivars	2006-07			2007-08			Average of years		
	Conventional N	Late-season N	Average	Conventional N	Late-season N	Average	Conventional N	Late-season N	Average
Tacettinbey	11.8	12.5	12.2B	12	13	12.5B	11.9	12.8	12.3C
Tatlicak-97	12.4	13.2	12.8A	12.2	13.4	12.8B	12.3	13.3	12.8B
Karma-2000	12.2	13.8	13.0A	12.5	13.9	13.2A	12.4	13.8	13.1A
Mean	12.1B	13.2A	12.7	12.2B	13.4A	12.8	12.2B	13.3A	
	$Lsd_{variety: 0.544}$ $Lsd_{N:0.444}$, $Lsd_{VarietyXN:0.540}$			$Lsd_{variety: 0.325}$ $Lsd_{N:0.266}$, $Lsd_{VarietyXN: 0.323}$			$Lsd_{variety: 0.204}$, $Lsd_{N:0.240}$ $Lsd_{VarietyXN: 0.305}$		
Cv	2.35			1.38			2. 00		

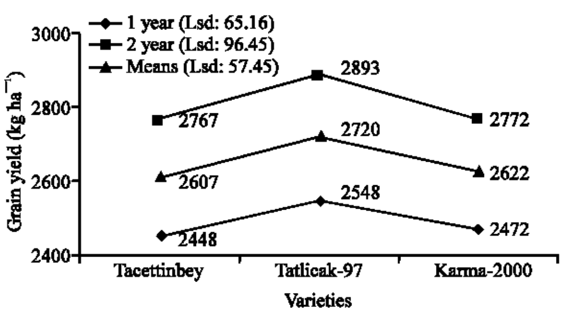

Fig. 1: Garin yield of cultivars

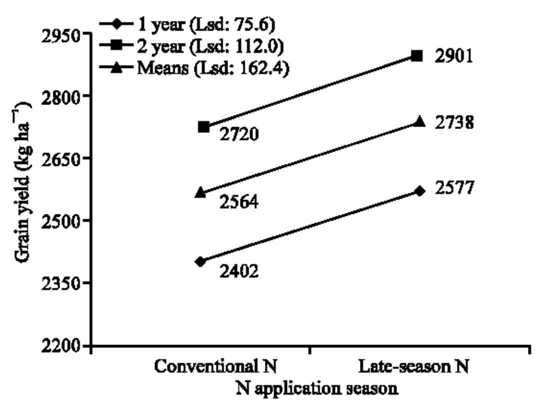

Fig. 2: Effect of N application timing on grain yield

late-season foliar nitrogen applications (2577, 2901 and 2738 kg ha^{-1}, respectively) compare with conventional N applications (2402, 2720 and 2564 kg ha^{-1}, respectively) (Fig. 2).

The grain yield of Triticale was significantly affected by cultivar × late-season N interaction. The highest grain yields were determined from Tatlicak cultivar x late-season N interaction (2646, 2987 and 2815 kg ha^{-1}, respectively) in both years and average of years. The lowest grain yields were obtained from Tacettinbey x conventional N interaction (2360, 2680 and 2535 kg ha^{-1}, respectively) in both years and average of years (Table 4).

All the cultivars, the higher grain yield was obtained in late-season N applications than conventional N application (Fig. 3).

Triticale cultivars had significant effect, $p \leq 0.05$, 0.01, on protein in both years and average of years. In the both years and average of years, the highest protein was obtained from Karma-2000 cultivar (13.0, 13.2 and 13.1%, respectively) compare with other Triticale cultivars. The lowest protein was obtained from Tacettinbey cultivar

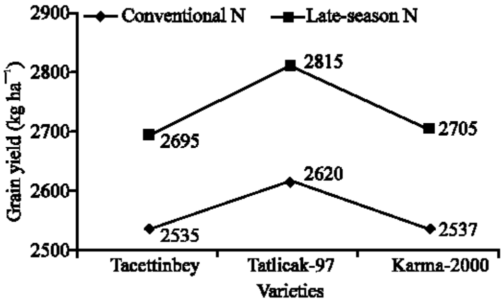

Fig. 3: Effect on grain yield of N application timing × cultivar interaction the average of years

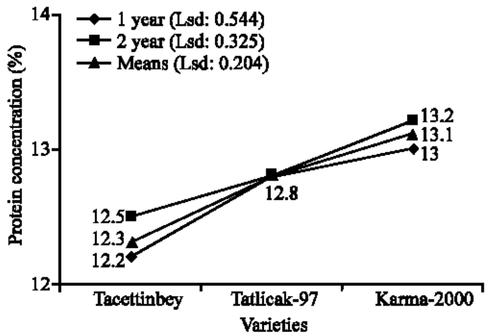

Fig. 4: Protein content of cultivars

(12.2, 12.5 and 12.3%, respectively) (Fig. 4). Differences in protein among cultivars result from genetic structures of variety (Feil, 1992). All the Triticale cultivars, the higher protein was obtained in 2nd than 1st year. Differences in protein between years result from growing period rain in the 2nd year of the study was higher than 1st year. Therefore, moisture supply may impact on grain protein content (Gauer *et al*., 1992). Under optimum moisture conditions, high rates of N are required to support the produce adequate protein content.

Nitrogen application timing in triticale had significant effect, $p \leq 0.01$, on protein content in both years and average of years. The data given in Table 4 indicated that there was a significant difference on protein content of N application time in both years. When, late-season foliar nitrogen application used, triticale protein content were significantly increased. During the 1st and 2nd years and the means of 2 years, the higher protein content was obtained from late-season foliar nitrogen applications (13.2, 13.4 and 13.3%, respectively) compare with conventional N applications (12.1, 12.2 and 12.2%, respectively). The higher protein content was obtained in late-season N applications than conventional N application (Fig. 5).

The protein content was significantly affected by cultivar × late-season N interaction. The highest protein

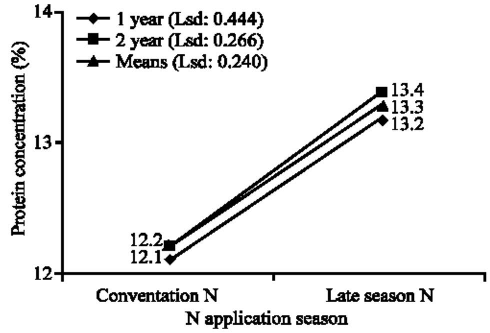

Fig. 5: Effect on protein content of N application timing

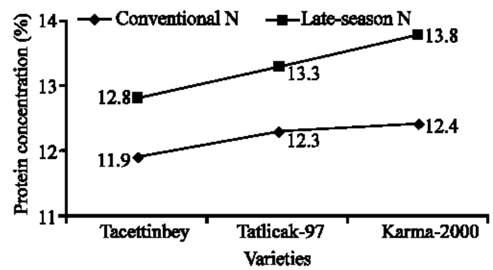

Fig. 6: Effect on protein content of N application timing × cultivars interaction in the average of years

content wasdetermined from Karma-2000 cultivar × late-season N interaction (13.8, 13.9 and 13.9%, respectively) in both years and average of years. The lowest protein content was obtained from Tacettinbey × conventional N interaction (11.8, 12.0 and 11.9%, respectively) in both years and average of years (Table 5). All the cultivars, the higher protein content was obtained in late-season N applications than conventional N application (Fig. 6).

As a result of correlation analysis of triticale, between grain yield and protein content of triticale was determined significant ($p \leq 0.01$) and positive connection ($r^2 = 0.451$). The relationship between relative grain yield and protein content was derived from the late-seson N treatment because it gave the greatest increase in grain protein content. In addition, N is a major component of dry matter production and accumulation in the grain (Anthony and Howard, 2003).

In the research, foliar N applications on triticale have increased grain protein. Foliar applied cereals may have a greater impact on grain protein content than soil-applied sources. Foliar N applications are actually absorbed through the leaf. The majority of the Afoliar-applied N is accessed by roots once the fertilizer washes off and reaches the soil (Alkier *et al*., 1972; Rawluk *et al*., 2000). Timing of N supply can also influence grain protein content. Nitrogen that is accessed by the crop early in the growing season generally has a major effect on vegetative growth and crop yield while the effect on grain protein content may be low, due to the biological dilution effect of the higher yield. Conversely, late season supplies of N generally affect protein more than yield. Since, there is little impact of late N supply on crop yield, there is less dilution of the protein produced by the enhanced grain production. In addition, N accessed later in the season may be more effectively channeled to the grain, as it is not immobilized in vegetative parts.

Grain protein content can decrease if the amount of added N is not adequate for potential yield (McNeal and Davis, 1954; Terman *et al*., 1969; Olson *et al*., 1976). If N in the soil is deficient, application of N fertilizer can increase both grain yield and protein content (Alkier *et al*., 1972; Akman and Kara, 2003). To produce a high-yielding, high quality triticale crop, the N supply must be balanced to the yield potential of the crop. Finney *et al*. (1957) indicated that the greatest grain protein increases occurred when foliar N applications were applied at anthesis (flowering) and that responses declined rapidly before or after that time. In some cases, they noted that N applied during the fruiting period could increase wheat protein from 10.8-21.0%. Many researchers have found that late-season topdress N additions as dry fertilizer materials were the most effective in attaining higher grain protein content (Fowler and Brydon, 1989; Stark and Tindall, 1992; Wuest and Cassman, 1992; Subedi *et al*., 2007). Pushman and Bingham (1976) have measured increases in grain protein content from applications of late-season N either as foliar sprays or dry topdress fertilizers even though early-season N applications were more than sufficient for potential grain yield.

CONCLUSION

While, environmental factors such as moisture and temperature have large effects on grain yield and protein content, production practices such as cultivar selection, seeding date and fertility management can also, influence yield and protein content. Balancing N supply with yield potential can optimize both crop yield and protein content.

The result obtained from present experiment indicated that effect of late-season N application were significant on both grain yield and grain protein content. Late-season N application increased grain yield on 6.8% and grain protein content on 9.0% compare with conventional N application.

According to our results, the highest triticale grain yield was obtained from Tatlicak cultivar × late-season N application interaction and highest grain protein content from Karma 2000 × late-season N application interaction.

It is advised that late-season N application and Tatlicak cultivar in order to obtain highest triticale yield. But it is able to advised late-season N application and Karma-2000 cultivar if the aim obtains high grain protein content.

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