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# INFLUENCE OF LATE-SEASON NITROGEN APPLICATION ON GRAIN YIELD, NITROGEN USE EFFICIENCY AND PROTEIN CONTENT OF WHEAT UNDER ISPARTA ECOLOGICAL CONDITIONS

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**ABSTRACT**

**The research has been conducted under Isparta ecological conditions during the 2006-2008 growing seasons. The purpose of the study was to determine the effects of late-season N application on grain yield, nitrogen use efficiency, nitrogen uptake efficiency, nitrogen utilization efficiency and grain protein content of wheat. The experiment was set up as Randomized Complete Block Design with a split-plot arrangement with three replications. Wheat cultivars were main plots, the nitrogen application times were subplots. Bread wheat cultivars (Gün-91, Gerek-79 and Altay-2000) were used. Nitrogen was applied as conventional N (two equal amounts at the time of seed sowing and tillering stage) and late-season N application (one-third of was applied during sowing, one-third at the tillering stage and the rest was applied as foliar at post-pollination growth stage). Effects of late-season foliar N application on grain yield, nitrogen use efficiency, nitrogen uptake efficiency, nitrogen utilization efficiency and grain protein content of wheat were observed. Grain yield, nitrogen use efficiency, nitrogen uptake efficiency, nitrogen utilization efficiency and grain protein content of wheat in both years of the study were significantly affected by N application time. The results showed that the grain yield, nitrogen use efficiency, nitrogen uptake efficiency and grain protein content were higher in the late-season N application than those of in the conventional N application in both years. But, nitrogen utilization efficiency was higher in conventional N application than late-season foliar N application in both years. The highest grain yield (3281 kg ha$^{-1}$), nitrogen uptake efficiency (71.3 %) and grain protein content (12.6 %) were obtained from Altay-2000 with cultivar x late-season N interaction in the second year. The highest nitrogen use efficiency (14.5 %) was obtained from Gün-91 with cultivar x late-season N interaction; and highest nitrogen utilization efficiency (37.6 %) was determined from Gerek-79 with cultivar x conventional N interaction in the second year.**

**Key words: wheat, grain yield, N use efficiency, protein**

## INTRODUCTION

Nitrogen use efficiency has been defined as units of economic yield per unit of soil N (Moll *et al*., 1982). Nitrogen use efficiency comprises N uptake efficiency and N utilization efficiency (Moll *et al*. 1982 and Ortiz-Monasterio *et al*.1997). Nitrogen uptake efficiency has been found to be a very important part of nitrogen use efficiency especially in low N conditions. On the other hand, nitrogen utilization efficiency is found to be an important part of nitrogen use efficiency under high N conditions (Ortiz-Monasterio *et al*., 1997). Strong (1995) found that low fertilizer efficiencies have been attributed to the timing of application, especially where fertilizer N was applied in the fall. The decline in efficiency of N use, N uptake, and N availability with increased fall applied N is indicative of substantial losses, and justifies reducing N rates in the fall, particularly in situations where residual N levels are high. N application as a top-dressing can improve fertilizer N recovery and N use efficiency in comparison to pre-sowing applications in dryland winter wheat. Mossedaq and Smith (1994) argued that timing of application should be considered as a critical factor in N fertilizer management in fall-sown spring wheat. Mi *et al*. (2000) investigated the effect of postanthesis N application to N-uptake and grain N content. They found that additional N application during flowering could increase N uptake and grain N content but the degree of increase differed with cultivars. 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 MacKown, 1987). Smith *et al*. (1991) observed positive increases in grain protein content of wheat 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. Bly and Woodward (2003) observed that post-pollination N application gave the highest grain protein content. Similarly, 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.

Foliar N applications are better absorbed through the leaf. Main source of nitrogen for the grain in cereals is nitrogen remobilized from the vegetative parts. The nitrogen accounts for 60 to 92% of the nitrogen accumulated in the grains at

**Table 1.** Climatic data of the Isparta region (2006-2008 growing seasons.)

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

Records of the Regional Meteorology Station, Isparta

maturity (Papakosta and Garianas, 1991). Genotype, ecological factors and agricultural practices are known to affect nitrogen translocation. It is therefore important to analyze the effect of each factor (genotype and agricultural practices) on the amount of nitrogen remobilized and on nitrogen remobilization efficiency. The objective of the study was to determine the effects on the grain yield, nitrogen use efficiency, nitrogen uptake efficiency, nitrogen utilization efficiency and grain protein content of wheat of late-season nitrogen application.

## MATERIALS AND METHODS

The experiment was conducted under Isparta ecological conditions in the 2006-07 and 2007-08 growing seasons.

Climatic data for crop growing seasons are shown in Table 1. Isparta has a 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 °C. 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 °C, total precipitation of 351.3 and 496.6 mm respectively (Table 1).

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

Soil in a depth of 60 cm was sampled after the harvest in different N application time, and data given in Table 2. In the N applied parcels, the lower soil N was determined in late-season N application parcels compare with conventional N application in both the first and second years. It showed that better absorbed by the plant of N applied to foliar. In other words, it is thought that N loses was higher in conventional N than late-season N application. Soil N content of in second year was lower than fist year. In growing period rain in the second year of the study were higher than first year. Therefore rain supply may impact on leaching of applied N in the second year of the study.

Experiment was set up as Randomized Complete Block Design in split plot arrangement with 3 replications. Wheat cultivars were main plots, the nitrogen application times were in subplots split within main blocks. The winter bread wheat cultivars commonly sown (Gün-91, Gerek-79 and Altay-2000) were used. Seeds were sown with 15x5 cm row spaces using a parcel sowing machine. The net plot size was 1.2x8m. Sowing was made in October in both years.

Gün-91: The variety is white spiked, awned, wintery, and resistant to lodging, drought, disease, harmful, and the variety is 90-100 cm height.

Gerek-79: The variety is a winter cultivar, awned, resistant to drought, cold, disease, harmful, and the variety is adaptation characteristic is wide.

Altay-2000: The variety is a brown seeded, awned, winter cultivar, with 1000 grain weight equaling to 33-35 g., and resistant to lodging, drought, cold, stres condition, disease, harmful, and the variety is 100-110 cm height.

Soil N was analyzed before planting. Nitrogen, ammonium nitrate ($NH_4NO_3$; 33.5%N) at a rate of 80 kg $ha^{-1}$, was applied as conventional N (two equal amounts at the time of seed sowing and tillering stage) and late-season foliar N application (one-third of was applied during sowing, one-third at the tillering stage and the rest was applied to foliar at post-pollination growth stage) (Zadoks *et al.*, 1974). Liquid N was foliar-applied by dilution. All of the phosphorous fertilizer (60 kg $P_2O_5$ $ha^{-1}$) was given as triple super phosphor before sowing.

**Table 2.** Physical and Chemical contents of soil of the experimental area

| Structure | Clay (%) | Silt (%) | Sand (%) | pH 1:1 | EC $10^6$ (dS/m) | $CaCO_3$ (Lime) | Organic Matter (g $kg^{-1}$) | P (mg $kg^{-1}$) | Nitrogen (%) |
|---|---|---|---|---|---|---|---|---|---|
| Loamy | 23,1 | 33,9 | 43,0 | 8,1 | 400 | 255 | 13,4 | 199 | 0,14 |

N content of soil after the harvest in the different N application time

| N application times | $NH_4 + NO_3$ (kg $ha^{-1}$) 2006-07 | $NH_4 + NO_3$ (kg $ha^{-1}$) 2007-08 |
|---|---|---|
| Conventional N | 2.9 | 2.2 |
| Late-season N | 2.0 | 1.2 |

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**Table 3.** Effect of nitrogen application time on grain yield (kg ha$^{-1}$) of wheat

| Cultivars | N application time | | | | | |
|---|---|---|---|---|---|---|
| | 2006-07 | | | 2007-08 | | |
| | CN | LSN | Average | CN | LSN | Average |
| **Gün-91** | 2462 b** | 2586 ab | 2524 C** | 2979 b* | 3235 a | 3107 A** |
| **Gerek-79** | 2534 b | 2648 a | 2591 B | 2683 bc | 2866 b | 2774 B |
| **Altay-2000** | 2663 ab | 2741 a | 2702 A | 3127 c | 3281 a | 3204 A |
| **Mean** | 2553 B** | 2658 A | **2605 B** | 2929B** | 3127A | **3028 A** |
| **Cv** | 2.02 | | | 3.72 | | |

*, **: Significant at 0.05 and 0.01 probability levels, respectively CN: Conventional N LSN: Late-season N

Regular cultural practices were kept for all treatments. When plants reached to harvest stage, 0.5 m was removed from each ends and one row from each side as border effects of plots. Remaining parts were harvested and threshed with threshing machine. In the study, grain yield, nitrogen use efficiency, nitrogen uptake, nitrogen utilization and grain protein content were determined in the following ways: Grain yield was calculated by multiplying by 10000/plot sizes (m$^2$). Grain nitrogen content was analyzed using a micro-Kjeldahl method. Grain protein content was calculated from the N % content in grain multiplied by a conversion factor of 6.25. The following N-efficiency parameters were calculated for each treatment (Moll *et al.,* 1982, Sowers *et al.*, 1994 and Delogu *et al*., 1998):

Nitrogen use efficiency = [yield at $N_x$ (kg ha$^{-1}$) - yield at $N_0$ (kg ha$^{-1}$)]/applied N (kg ha$^{-1}$).

Nitrogen uptake efficiency = [total aboveground plant N at $N_x$ (kg ha$^{-1}$) - total aboveground N at $N_0$ (kgha$^{-1}$)] / applied N (kg ha$^{-1}$).

Nitrogen utilization efficiency = [yield at $N_x$ (kg ha$^{-1}$)-yield at $N_0$ (kg ha$^{-1}$)] / [total aboveground plant N at $N_x$ (kgha$^{-1}$)-total aboveground plant N at $N_0$ (kgha$^{-1}$)].

All the data were analyzed with the analysis of variance (ANOVA) using SAS Statistical Package Program. Means were compared using the DUNCAN test.

## RESULTS AND DISCUSSION

The mean grain yield, nitrogen use efficiency, nitrogen uptake efficiency, nitrogen utilization efficiency and grain protein content of wheat was significantly influenced by the year. The means data of the second year were higher than those of fist year. Differences between the might be due to longer raining years growing period in the second year as compared to the first. Moisture supply may affect crop yield, N content and the capacity of plant utilization of available N. Similar results were also obtained in other studies have reported that grain yield, nitrogen use efficiency, nitrogen uptake efficiency, nitrogen utilization efficiency and grain protein content also varied depending on year and fertilization time (Cox *et al*., 1986; Papakosta and Garianas, 1991).

*Grain yield*

Wheat cultivars had means significantly different ($P \leq 0.01$) in both years. The highest grain yield was obtained from Altay-2000 cultivar (2702 and 3204 kg ha$^{-1}$ respectively) as compared with others.

Nitrogen application time had significant effect ($P \leq 0.01$) on grain yield in both years. When nitrogen was applied in late-season foliar, grain yield significantly increased. The highest grain yield was obtained from the late-season foliar nitrogen applications (2658 and 3127 kg ha$^{-1}$ respectively) as compared with the conventional N application (2553 and 2929 kg ha$^{-1}$ respectively) (Table 3).

The cultivar x N application time interaction was significant. The highest grain yields were obtained from Altay-2000 cultivar in late-season N applications (2741 and 3281 kg ha$^{-1}$ respectively) in both years. The lowest grain yields were obtained from Gün-91 x conventional N application interaction (2462 kg ha$^{-1}$) in the firs year and Gerek-79 x conventional N application interactions (2683 kg ha$^{-1}$) in the second year (Table 3). In generally, higher grain yield was obtained in late-season N applications than the conventional N applications.

**Table 4.**Effect of nitrogen application time on nitrogen use efficiency (%) of wheat

| Cultivars | N application time | | | | | |
|---|---|---|---|---|---|---|
| | 2006-07 | | | 2007-08 | | |
| | CN | LSN | Average | CN | LSN | Average |
| **Gün-91** | 9.1 b* | 10.2 a | 9.6 | 12.3 b** | 14.5 a | 13.4 |
| **Gerek-79** | 10.0 a | 11.0 a | 10.5 | 9.3 d | 10.9 c | 10.3 |
| **Altay-2000** | 10.1 a | 10.8 a | 10.4 | 12.6 b | 13.9 a | 13.2 |
| **Mean** | 9.8 B* | 10.7 A | **10.2 B** | 11.4 B** | 13.1 A | **12.3 A** |
| **Cv** | 5.8 | | | 7.0 | | |

*, **: Significant at 0.05 and 0.01 probability levels, respectively, CN: Conventional N LSN: Late-season N

**Table 5.** Effect of nitrogen application time on nitrogen uptake (%) of wheat

| Cultivars | N application time | | | | | |
|---|---|---|---|---|---|---|
| | 2006-07 | | | 2007-08 | | |
| | CN | LSN | Average | CN | LSN | Average |
| **Gün-91** | 33.4 b** | 45.0 a | 39.2 | 55.4 b** | 68.2 a | 61.8 |
| **Gerek-79** | 30.9 b | 35.4 b | 33.2 | 53.8 b | 65.9 a | 59.8 |
| **Altay-2000** | 34.9 b | 44.1 a | 39.5 | 65.7 a | 71.3 a | 68.5 |
| **Mean** | 33.1 B * | 41.5 A | **37.3 B** | 58.3 B** | 68.5 A | **63.4 A** |
| **Cv** | | 10.49 | | | 6.64 | |

*, **: Significant at 0.05 and 0.01 probability levels, respectively CN: Conventional N LSN: Late-season N

*Nitrogen Use Efficiency*

Nitrogen application time in wheat had significant effect on nitrogen use efficiency in both years. When late-season foliar nitrogen application was used, wheat nitrogen use efficiency was significantly increased. The highest nitrogen use efficiency was obtained from late-season nitrogen application (10.7 and 13.1 % respectively) as compared to conventional N application (9.8 and 11.4 % respectively) (Table 4).

The highest nitrogen use efficiency was determined from Gerek-79 cultivar in late-season N application (11.0 %) in the first year, and Altay-2000 cultivar in the late-season N application (13.9 %) in the second year. The lowest nitrogen use efficiency was obtained from Gün-91 in conventional N application (9.1 %) in the first year, and Gerek-79 in conventional N application (9.3 %) in the second year (Table 4).

*Nitrogen Uptake Efficiency*

Nitrogen application time in wheat had significant effect on nitrogen uptake efficiency in both years. Nitrogen uptake efficiency was significantly increased by late-season foliar nitrogen application. The highest nitrogen uptake efficiency was obtained from late-season nitrogen applications (41.5 and 68.5 % respectively) as compared to the conventional N application (33.1 and 58.3 % respectively) (Table 5).

The nitrogen uptake efficiency had significant cultivar x N application time interaction. So, the highest nitrogen uptake efficiency was obtained from Gün-91 in late-season N applications (45.0 %) in the first year and Altay-2000 by late-season N application (71.3 %) in the second year (Table 5).

*Nitrogen Utilization Efficiency*

Wheat cultivars had means significantly different in both years. The highest nitrogen utilization efficiency was obtained from Gün-91 cultivar (22.0 %) in the first year and Gerek-79 (35.2 %) in the second year.

Nitrogen application time in wheat had significant effect on nitrogen utilization efficiency in the second year, but non-significant in the first year of the study. The highest nitrogen utilization efficiency was obtained from conventional N application (19.6 and 31.4 % respectively) as compared to the late-season N application (19.2 and 26.7 % respectively) (Table 6).

The nitrogen utilization efficiency had significant cultivar x N application interaction. The highest nitrogen utilization efficiency was determined from Gün-91 and Gerek-79 cultivars in conventional N application (22.6 and 37.6 %, respectively) (Table 6).

*Grain protein content*

Wheat cultivars had significant the differed grain protein content in both years. The highest grain protein content was obtained from Altay-2000 cultivar (12.3 and 12.4 % respectively) as compare to other wheat cultivars. The lowest grain protein content was obtained from Gerek-79 cultivar (11.9 and 12.2 % respectively) in both years.

The data regarding with the grain protein content are shown in Table 7. Data showed that grain protein content was affected significantly by N application time in both years. The highest grain protein content was obtained from late-season N application (12.1 and 12.4 % respectively) as compare to the conventional N (11.9 and 12.1 % respectively) (Table 7).

**Table 6.** Effect of nitrogen application time on nitrogen utilization efficiency (%) of wheat

| Cultivars | N application time | | | | | |
|---|---|---|---|---|---|---|
| | 2006-07 | | | 2007-08 | | |
| | CN | LSN | Average | CN | LSN | Average |
| **Gün-91** | 22.6 a** | 21.4 a | 22.0 A* | 27.3 b * | 22.3 c | 24.8 B** |
| **Gerek-79** | 17.4 b | 16.6 b | 17.0 B | 37.6 a | 32.6 a | 35.2 A |
| **Altay-2000** | 19.0 ab | 19.6 ab | 19.3 C | 29.3 ab | 25.0 b | 27.2 B |
| **Mean** | 19.6 | 19.2 | **19.4 B** | 31.4 A* | 26.7 B | **29.0 A** |
| **Cv** | | 11.5 | | | 10.64 | |

*, **: Significant at 0.05 and 0.01 probability levels, respectively CN: Conventional N LSN: Late-season N

**Table 7.** Effect of nitrogen application time on grain protein content (%) of wheat

| Cultivars | N application time | | | | | |
|---|---|---|---|---|---|---|
| | 2006-07 | | | 2007-08 | | |
| | CN | LSN | Average | CN | LSN | Average |
| **Gün-91** | 12.0 b** | 12.1 b | 12.1B* | 12.2 c* | 12.3 b | 12.3 B* |
| **Gerek-79** | 11.8 c | 12.0 b | 11.9C | 12.1 c | 12.3 b | 12.2 B |
| **Altay-2000** | 12.1 b | 12.4 a | 12.3A | 12.3 b | 12.6 a | 12.4 A |
| **Mean** | 11.9 B** | 12.1 A | **12.0 B** | 12.1B** | 12.4 A | **12.2 A** |
| **CV** | | 2.16 | | | 1.59 | |

*, **: Significant at 0.05 and 0.01 probability levels, respectively CN: Conventional N LSN: Late-season N

Grain protein content of wheat had significantly by cultivar x N application interaction**.** Therefore, the highest grain protein content was determined from Altay-2000 cultivar in late-season N application (12.4 and 12.6 % respectively). The lowest grain protein content was obtained from Gerek-79 in conventional N application (11.8 and 12.1 % respectively) in both years (Table 7).

Wheat cultivars had different grain yield, nitrogen use efficiency, nitrogen uptake efficiency, nitrogen utilization efficiency and grain protein content. Differences in grain yield, nitrogen use efficiency, nitrogen uptake efficiency, nitrogen utilization efficiency and grain protein content among cultivars might result from the genetic structures of variety, root morphology, absorption of ion, ecological factors, agricultural practices (Barbottin *et al.*, 2005), uptake of nitrate (Rodgers and Barneix, 1988) and N remobilization (Van Sanford and Mac Kown, 1986). Differences among cultivars for nitrogen use efficiency are largely due to variation in the utilization of accumulated N before anthesis, especially under low N supply (Moll *et al.*, 1982). The large variation in cultivars N use efficiency reported by Bellidoa *et al.* (2005) studies may be due to differences in climate, cultivar and management practices. Wheat varieties with a high harvest index and low forage yield have low plant N loss and increased nitrogen use efficiency (Kanampiu et al., 1997). Other work by Karrou and Maranville (1993) suggests that wheat varieties that produce more seedling dry matter with greater N accumulation are not necessarily the ones that use N more efficiently. Furthermore N assimilation after anthesis is needed to achieve high wheat yields (Cox *et al.*, 1986; Muurinen *et al.*, 2006) and high nitrogen use efficiency. The influence of the environment on post-anthesis N uptake has been noted (Gregory *et al.*, 1981) due to genotype × environment interaction.

In the study, grain yield, nitrogen use efficiency, nitrogen uptake efficiency and grain protein content, except nitrogen utilization efficiency in wheat increased in late-season N application. In cereals the main source of nitrogen for the grains is remobilized nitrogen from the vegetative parts. This source accounts for 60 to 92% of the nitrogen accumulated in the grains at maturity (Papakosta and Garianas, 1991). The amount of nitrogen remobilized depends on nitrogen remobilization efficiency and cultivar. Foliar N applications are accepted to be better absorbed by leaves. The majority of the "foliar-applied" N is accessed by roots once the fertilizer washes off and reaches the soil (Rawluk *et al.* 2000). In addition, N accessed later in the season may be more effectively channeled to the grain, as it is not immobilized in vegetative parts. Finney *et al.* (1957) reported that N applied during the fruiting period could increase wheat protein from 10.8 to 21.0%. Bulman and Smith (1993) reported that applications of N near flowering increased post-flowering N uptake and grain protein content. Gregory *et al.* (1981) reported N uptake during grain fill accounted for as much as 50 % of the grain protein content at maturity.

## CONCLUSION

The result obtained from the present experiment confirmed that the effects of late-season N application on grain yield, nitrogen use efficiency, nitrogen uptake efficiency and grain protein content in wheat. The highest grain yield, nitrogen use efficiency, nitrogen uptake efficiency and grain protein content were obtained from late-season N application.

Based on the results of the research, Altay-2000 cultivars had higher grain yield, nitrogen use efficiency, nitrogen uptake efficiency and grain protein content as compare to the others cultivar.

In conclusion, we could advise late-season N application and Altay-2000 cultivar due to its higher grain yield, nitrogen use efficiency, nitrogen uptake efficiency and grain protein content.

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