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# Effect of Nitrogenous Fertilizer on Grain Yield and Grain Protein Concentration in Winter Wheat

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Baking quality of wheat in commercial cultivars generally depends on the protein concentration of the grain. Grain yield and grain protein concentration (GPC) in wheat is influenced by genotype and nitrogeneous fertilizer. However, nitrogeneous fertilizer can increase residual soil nitrate after harvest. The purpose of this study was to evaluate the effect of nitrogeneous fertilizer on grain yield, GPC and the relation grain yield and GPC in winter wheat. The experiments were conducted during two growing seasons in Tokat conditions of Turkey. Four nitrogen treatments (50, 100, 150 and 200 kg N/ha) were applied on two cultivars (Bezostaja-I and Momtchill). GPC and grain yield varied depending mainly on the year, genotype and nitrogen rates. Nitrogeneous fertilizer increased grain yield and GPC. However, the increases in grain yields were not significant when increasing from 100 kg N/ha to higher nitrogen rates. GPC was significantly affected by nitrogen rate (except for Momtchill in 2002) and GPC increased along with increasing nitrogeneous fertilizer rates, but the responses to added nitrogen were variable in genotypes and years. GPC in Bezostaja-I increased in a quadric manner as grain yield increased, whereas in Momtchill, the response was linear (in 2002). The results of this study show that high rates of nitrogeneous fertilizer may increase GPC and grain yield. On the other hand, the application of nitrogen at rates (more than 100-150 kg N/ha) exceeding plant utilization represents an unnecessary input cost to wheat producers and may contribute to the leaching of soil nitrate into the ground water. Therefore, the requirements for high GPC and grain yield must be accompanied by farm practices that make efficient use of the nitrogeneous fertilizer and minimize the risk of nitrate losses to water supplies.

**Key Words: Winter wheat, Grain protein concentration, Grain yield, Nitrogenous fertilizer.**

## INTRODUCTION

Nitrogen is a key element in achieving consistently high yield cereals and has been recognized for a long time as a critical nutrient for wheat[1]. Nitrogen nutritional needs of wheat are typically met by the application of nitrogeneous fertilizer. The amount of nitrogen applied to winter wheat must be managed to ensure that nitrogen is available through the growing season because of its important role in enhancing both vegetative and reproductive development. In many researches[2-4], it was noticed that nitrogeneous fertilizer significantly increased grain yield, but grain yield responses to increase nitrogen quickly diminished when cultivar yield potential or environmental factors, such as moisture, limited grain yield.

Baking quality of wheat in commercial cultivars generally depends on the protein concentration of the grain[5,6]. Protein concentration also depends on genotype and is influenced by the environment (mainly climate during the grain filling period), soil nitrogen and rate and time of supplemental nitrogen application[7,8]. Temperature, rainfall and solar radiation during grain filling are the climatic factors with the most marked effects on protein concentration in wheat[9]. Growing conditions leading to long grain-filling periods normally result in well-filled kernels with a low protein concentration[7]. On the other hand, there are large differences among wheat cultivars in their protein concentration[10,11].

Nitrogeneous fertilizer management offers the opportunity for increasing wheat protein content and quality. In order to increase protein concentration in grain, nitrogeneous fertilizer has been applied at different levels and growing stages, and it was found that protein concentration in grain was increased with nitrogeneous fertilizer until certain levels[2,9,12]. In some studies, negative relationships between grain yield and grain protein concentration have also been reported in cereals[13,14]. Fowler[2] also reported that the large increases in grain yield and grain protein concentration achieved with nitrogeneous fertilizer stand in sharp contrast to the negative correlation that is normally observed between grain protein concentration and grain yield when only cultivars differences are considered. Therefore, the important role that nitrogeneous fertilizer management has to play in optimizing grain yields and the maintenance of grain quality standards must be emphasized in efficient wheat production systems. On the other hand, although high application rates of nitrogeneous fertilizer may increase quality and grain yield in wheat, it may also result in nitrate pollution[15,16]. Nitrogen leaching is a widespread concern not only because of the wasted fertilizer, but also because of regulations limiting nitrate concentrations in drinking water[17].

Wheat is one of important cultural plants in Tokat region and Bezostaja-I and Momtchill cultivars are mostly preferred by the farmers living in the region. It was recently noticed the farmers have unconsciously used higher nitrogeneous fertilizer. This is a dangerous step because it have increased nitrate pollution. The objectives of this research were to study and quantify the effects of nitrogen and environment on grain protein concentration and grain yield and to evaluate the relation grain yield and GPC in winter wheat.

## EXPERIMENTAL

Field experiments with wheat were conducted during two growing seasons (2000-2001 and 2001-2002) in Tokat in the Black Sea Region of Turkey. The experiments were conducted at the farmer fields which were used for growing wheat in previous season. Soil types were medium alkaline (pH = 8.50) and sand-tan. The organic matter and available phosphorus contents were 1.07% and 64.1 kg/ha, respectively. The experiment was arranged in a randomized block design in a split plot arrangement and four replicates. The seedbed was conventionally prepared and fertilized with 80 kg P/ha before sowing. Bezostaja-I and Momtchill cultivars were used in the experiments. The farmers living in the region mostly prefer these cultivars because both of them are resistant to lodging and many diseases. On the other hand, their responses to nitrogen are very good. Each plot, consisting of six 6 m rows, 0.2 m apart was sown by hand at a density of 400 seeds/$m^2$ (November 25, 2000 and December 3, 2001). The cultivars were assigned to the main plots, nitrogen treatments to sub-plots. Nitrogen rate treatments were: 0, 50, 100, 150 and 200 kg/ha broadcast applied as ammonium sulphate. Half of nitrogen was applied at seeding, the other half was applied in the beginning of tillering. To control the weeds in experimental fields, herbicide (Puma, 800 mL/ha) was used each year in the beginning stem elongation.

At maturity, rows 2, 3, 4 and 5 of each plot were harvested except for a 0.50 m border at each end. Plot yields were weighed and converted to kg/ha. Nitrogen in grain samples was determined by using Kjeldahl method and GPC for each plot was determined as N × 5.7.

All data were analyzed with analysis of variance by using TARIST Soft Package[18]. Differences among cultivars or nitrogen rates were determined by Duncan's multiple range test ($p < 0.05$). Bartlett's test for homogeneity of variance was performed on plot variances. For two measured characteristics, data could not be combined over growing seasons due to heterogeneity of variances as measured by Bartlett's test procedure. Regression analyses of treatments were used to plot curves that best described the response of grain yield and GPC with nitrogeneous fertilizer application. Linear or quadric equations are selected if the regressions are significant ($p < 0.05$).

## RESULTS AND DISCUSSION

Pre-sowing soil tests indicated that available nitrogen and organic matter content (1.07 %) in the 40 cm surface of the trails were insufficient. Grain yield and GPC significantly responded to added nitrogen because of deficiencies in soil available nitrogen.

Analysis of variance for grain yield indicated that differences due to years, cultivars and rate of nitrogeneous fertilizer were significant (unpresented data). The growing season weather conditions significantly influenced on grain yield. The average grain yields in 2001 were 3011 compared to 4926 kg/ha in 2002 (Tables 2 and 3), probably because of higher precipitation and lower maximum temperatures during filling in 2002. The monthly rainfall for June and July 2001 were 5.6 and 1.0 mm, respectively (Table-1). However, in June and July 2002, rainfalls were 57.6 and 37.6 mm. Therefore, in this study, better rainfall distribution in second year caused higher grain yield for both cultivars in this year.

TABLE-1
MONTHLY TEMPERATURE, PRECIPITATION, AND RELATIVE MOISTURE RATE (%) IN TOKAT, TURKEY

| Month | Precipitation (mm) | | | Temperature (ºC) | | | Relative moisture rate (%) | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2000 - 2001 | 2001 - 2002 | Long years | 2000 - 2001 | 2001 - 2002 | Long years | 2000 - 2001 | 2001 - 2002 | Long years |
| September | 20.4 | 11.4 | 17.9 | 19.6 | 18.8 | 17.9 | 66.8 | 75.0 | 58.0 |
| October | 24.0 | 15.6 | 34.2 | 11.6 | 11.6 | 12.5 | 80.9 | 74.2 | 63.7 |
| November | 0.2 | 73.4 | 50.1 | 5.6 | 7.4 | 7.1 | 74.3 | 79.6 | 67.8 |
| December | 29.4 | 50.5 | 47.2 | 3.4 | 5.1 | 3.3 | 85.0 | 77.2 | 69.7 |
| January | 2.6 | 45.1 | 41.7 | 2.6 | -4.5 | 1.3 | 82.9 | 90.6 | 66.5 |
| February | 35.6 | 20.4 | 33.4 | 4.9 | 4.1 | 2.9 | 73.4 | 76.7 | 61.8 |
| March | 19.3 | 29.2 | 40.2 | 11.3 | 9.3 | 7.1 | 64.4 | 63.8 | 57.9 |
| April | 39.6 | 68.4 | 61.6 | 13.5 | 11.1 | 12.5 | 68.0 | 76.6 | 59.1 |
| May | 92.2 | 16.8 | 60.5 | 14.4 | 15.6 | 16.3 | 75.9 | 65.1 | 56.5 |
| June | 5.6 | 57.6 | 40.6 | 20.2 | 18.8 | 19.6 | 60.6 | 76.4 | 53.7 |
| July | 1.0 | 37.6 | 10.5 | 23.6 | 23.2 | 22.0 | 64.4 | 70.4 | 55.4 |
| August | 1.2 | 11.2 | 7.1 | 23.3 | 21.4 | 21.7 | 65.5 | 72.1 | 56.5 |
| Total | 271.1 | 437.2 | 445.0 | | | | | | |
| Mean | | | | 12.8 | 11.8 | 11.9 | 71.9 | 74.8 | 60.6 |

There were significant cultivar × nitrogen fertilizer interactions for grain yield in 2001 and 2002 (unpresented data) and Momtchill performed better than Bezostaja-I in both years. Fowler[2], Frederick and Camberato[3], Lloveras *et al.*[9] also reported that there were genotypic differences for grain yield.

Nitrogenous fertilization increased yields in both cultivars and years (Tables 2 and 3). The highest yields in Bezostaja-I were achieved as 2580 and 5232 kg/ha with 150 and 200 kg N/ha in 2001 and 2002, respectively. However, for grain yields, there were no differences among the rates of 100, 150 and 200 kg N/ha in both years. The results for grain yield in Momcthill were considerably different. In 2001, the highest grain yield was achieved with 150 kg N/ha (4300 kg/ha) and the differences among this rate of nitrogen and the other rates were significant (Table-2). The grain yield at 200 kg N/ha decreased and this small reduction in grain yield with increasing nitrogen could have been the result of probably due to the lower rainfall in this year. Conversely, in 2002, all nitrogen rates increased grain yield, but the increases after the rate of 100 kg N/ha were not significant (Table-3). While the yield-increasing effects of nitrogeneous fertilizer application are well known, the results of this experiment confirm the results of Frederick and Camberato[3] and Staggenborg *et al.*[4] that grain yield increased with increasing nitrogen fertilization rates. As seen in Tables 2 and 3, genotype responses to nitrogeneous fertilization were higher in 2002. In this study, especially, rainfall during the grain filling could have a significant effect on the yield response of winter wheat to nitrogeneous fertilization because environmental factors, such as drought stress, may influence the amount of soil nitrogen utilized by winter wheat[3].

TABLE-2
MAIN GRAIN YIELD AND GRAIN PROTEIN CONCENTRATION OF WINTER WHEAT GROWN IN 2001

| | Grain yield (kg/ha) | | Grain protein concentration (g/kg) | |
|---|---|---|---|---|
| N (kg/ha) | Bezostaja-I | Momtchill | Bezostaja-I | Momtchill |
| 0 | 2023 b | 3553 b | 113.8 b | 100.1 b |
| 50 | 2120 b | 3623 b | 121.0 b | 106.7 ab |
| 100 | 2363 ab | 3630 b | 122.6 b | 118.6 ab |
| 150 | 2580 a | 4300 a | 130.7 ab | 116.9 ab |
| 200 | 2557 a | 3353 b | 146.9 a | 126.6 a |
| Mean | 2329 **b** | 3692 **a** | 128.0 **a** | 113.8 **b** |

*Means followed bye the same letter within a column are not significantly different at $p < 0.05$

According to analysis of variance for GPC, the differences due to years, cultivars and rate of nitrogeneous fertilization were significant (unpresented data). The average GPC considerably decreased in 2002. The average GPC of all treatments was 120.9 and 107.9 in 2001 and 2002, respectively (Tables 2 and 3). Low GPC in 2002 was probably associated with favorable growing conditions. As seen in Table-1, the 2002 growing season conditions were more favourable for grain yield and the genotypes were more productive in 2002 because of the available moisture and favourable temperatures during growing season. These conditions (higher rainfall in 2002) leaded to longer grain filling period, higher grain yields, and lower GPC. In 2001, increased temperature and lower rainfall (in June and July) during grain filling tended to increase GPC. This result agrees with reports of Fowler[2] and Lloveras *et al.*[9] and Stone and Savin[19].

Two cultivars differed in GPC and Bezostaja-I had higher GPC in both years. Average GPC for Bezostaja-I were 128.0 and 114.2, for Momtchill were 113.8 and 101.6 g/kg in 2001 and 2002, respectively (Tables 2 and 3). Field experiments have shown that genetic variability for nitrogen uptake and GPC exists in small grains[10,11,20-22] and GPC is influenced by the environment[5-8].

In these conditions, Bezostaja-I, which has lower yield potential than Momtchill, had higher GPC in both years. This result agreed with reports of Fowler[2] showing that higher yielding genotypes have lower GPC those that of lower yielding genotypes.

TABLE-3
MAIN GRAIN YIELD AND GRAIN PROTEIN CONCENTRATION OF WINTER WHEAT GROWN IN 2002

| | Grain yield (kg/ha) | | Grain protein concentration (g/kg) | |
|---|---|---|---|---|
| N (kg/ha) | Bezostaja-I | Momtchill | Bezostaja-I | Momtchill |
| 0 | 3400 b | 3807 b | 102.8 b | 91.0 |
| 50 | 4343 b | 3917 b | 106.4 b | 97.2 |
| 100 | 4731 a | 5780 a | 112.7 b | 104.0 |
| 150 | 5061 a | 6387 a | 115.4 b | 105.1 |
| 200 | 5232 a | 6600 a | 133.6 a | 110.6 |
| Mean | 4553 **b** | 5298 **a** | 114.2 **a** | 101.6 **b** |

*Means followed bye the same letter within a column are not significantly different at $p < 0.05$

Findings in this study indicated GPC was significantly affected by nitrogen rate (except for Momtchill in 2002). GPC increased together with increasing nitrogeneous fertilization rates and the highest GPC was achieved with the highest nitrogen rate (200 kg N/ha) for both years (Tables 2 and 3). The increases for GPC were higher for Bezostaja-I as 29.1 and 30.0 % in 2001 and 2002, respectively. Also, the increases for Momtchill were 26.5 and 19.7%. On the other hand, in 2002, the differences among 200 kg N/ha and the other nitrogen rates for GPC in Bezostaja-I were significant while the increasing after 150 kg N/ha was not significant in 2001. The results for Momtchill were considerably different and the increases after 50 kg N/ha were not significant in 2001. Nitrogen is the basic building of protein and it has been long recognized as a critical nutrient for wheat[1]. Therefore, applied nitrogen increased GPC in this study. Delogu *et al.*[12], Fowler[2], Howard and Lessman[23], Kelly[24], Lloveras *et al.*[9], Staggenborg[4] and Woodard and Bly[25] reported that supplemental nitrogen increased GPC in wheat. Baking quality of wheat in commercial cultivars generally depends on the GPC of the grain[5,6] and therefore, the results here are important.

**Relation between grain protein concentration and grain yield**

There were significant quadric relations between grain yield and GPC for Bezostaja-I in both years ($r^2 = 0.83$ and 0.84 in 2001 and 2002) but they varied depending mainly on the year (Fig. 1). In 2001, in beginning, both the grain yield and GPC increased linearly, but later grain yield did not increase linearly while GPC did. In 2002, a more different relation between grain yield and GPC was observed. In this year, there was at first a sharp increase of grain yield and GPC, later grain yield decreased sharply while GPC increased. This difference between years was probably due to climatic conditions in experiment years. Environmental conditions during the growing season have a significant effect on the yield and GPC response of winter wheat[3] to nitrogeneous fertilization. In 2001, drought stress during grain filling may have influenced the amount of soil nitrogen utilized by winter wheat and therefore, grain yield may not increased.

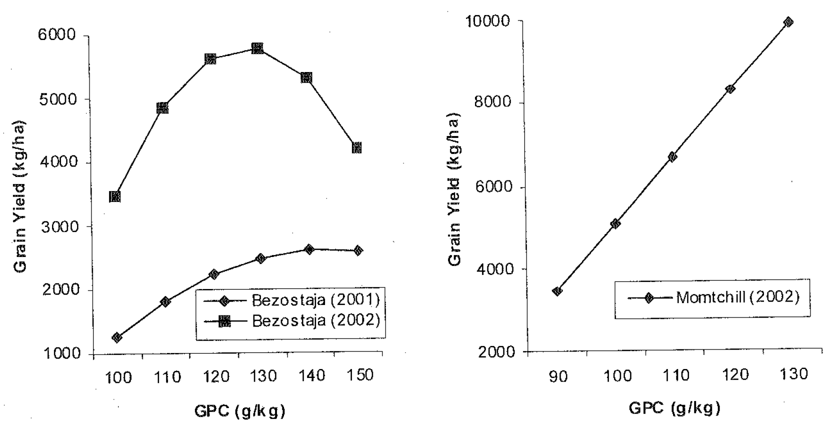


Fig. 1. Relationships between grain yield and grain protein concentration (GPC)

In contrast to Bezostaja-I, the relation between grain yield and GPC in Momtchill was significant only in 2002 ($r^2 = 0.86$), and this relation was linear (Fig. 1). In this year, large GPC responses to added nitrogen were accompanied by increases in grain yield. The differences in Momtchill were a result of genotype and environment conditions. Fowlor[12] reported that there was a positive correlation between grain yield and GPC due to increased nitrogen availability, but these results did not agree with reports of Bulman and Smith[13] and Gan *et al.*[26], Torp[14] showed that there were negative relations between grain yield and GPC.

## Conclusion

Bezostaja-I and Momtchill cultivars used in experiments are mostly preferred by the farmers living in the region. The farmers have unconsciously used higher nitrogeneous fertilizer to obtain higher grain yield and quality recently. The results also showed that nitrogeneous fertilization generally increased grain yield and GPC. However, the increases in grain yields were not significant when increasing from 100 kg N/ha to higher nitrogen rates. GPC was significantly affected by nitrogen rate (except for Momtchill in 2002) and GPC increased with increasing nitrogeneous fertilization rates, but the responses to added nitrogen were variable in genotypes and years. The highest GPC was achieved with the highest nitrogen rate (200 kg N/ha) for both years. The differences among at 200 kg N/ha and other nitrogen rates were significant in Bezostaja-I in 2002 while the increasing after 150 kg N/ha was not significant in 2001. The results for Momtchill were considerably different and the increases after 50 kg N/ha were not significant. It was observed that nitrogeneous fertilization increased GPC more than grain yield when available water in soil is limited.

On the other hand, there was a positive correlation between grain yield and GPC due to increased nitrogen availability and GPC in Bezostaja-I increased in a quadric manner as grain yield increased, whereas in Momtchill, the response was linear (in 2002). The result of regression analysis showed that the nitrogen rate required to maximize grain nitrogen was greater than the nitrogen rate maximize grain yields.

As a result, this study showed that high rates of nitrogeneous fertilization applied to these cultivars may increase GPC and grain yield, but the effect of nitrogeneous fertilization varies depending environmental conditions and the application of nitrogen at rates (more than 100-150 kg N/ha) exceeding plant utilization represents on the other hand an unnecessary input cost to wheat producers and may contribute to the leaching of soil nitrate into the groundwater[15,16]. In the present situation of increasing environmental concerns, the requirements for high GPC must be accompanied by farm practices that make efficient use of the nitrogen containing fertilizer and minimize the risk of nitrate losses to water supplies.

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