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Full Length Research Paper

Response of grain and protein yields of triticale varieties at different levels of applied nitrogen fertilizer

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The grain yield and grain protein content of winter triticale in dry farming can be significantly affected by environmental conditions and different nitrogen (N) levels. Two year field trials with six winter triticale cultivars (Tatlicak, 97; Presto, 2000; Karma, 2000; Melez, 2001; Mikham, 2002 are registered in Turkey and Samur Sortu in Azerbaijan) were conducted in Central Anatolia, Turkey to investigate the possible influences of nitrogen levels on grain yield, grain protein content and grain protein yields. Nitrogen level applications included: N_0 (control), N_1 (0+40 kg ha-^{1}), N_2 (40+0 kg ha-^{1}), N_3 (40+40 kg ha-^{1}) and N_4 (80+80 kg ha-^{1}) (the first amount used for sowing and the second top dressed). There were differences between cultivars in response to a variation in N level. Grain yield, grain protein content, and grain protein yield showed a highly significant response to N levels, increasing with rising N levels till N_3 level. Grain yield, protein content and protein yield were highest at N_3 (40+40 kg ha^{-1}) level. The grain yield of triticale did not differ at N_1 and N_2 (total 40 kg N ha^{-1}) levels depending on application time. Melez, 2001 cultivar produced higher performance than the other triticale cultivars.

Key words: Nitrogen fertilizer, triticale, protein yield, grain yield.

INTRODUCTION

Increased grain yield and protein content are two important goals in cereal production. Grain protein content is considered to be as important as grain yield, since both types of content contribute to end-use quality, and determine the economic value of the crop. The grain protein percentage generally depends on nitrogen (N) in soil. Nitrogen deficiencies generally affect crop growth, decrease grain protein content, and ultimately decrease grain yield and grain protein yield (Lopez-Bellido et al., 1998; Zheng et al., 2009).

Grain protein contents are the result of a complex interaction between N and water availability, grain yield and temperature. Climatic variables affect grain protein content differently from one year to another during the grain filling period, because the amount and distribution of precipitation are key environmental factors exerting a strong influence on protein content (Garrido-Lestache at al., 2004). Therefore, in terms of increasing the yield and protein content of cereal, weather conditions and soil residual N could have an effect on the decision of whether or not the fertilizer N is to be used as a top-dressing (Gulmezoglu and Kinaci, 2004). Much of the research on the principles of efficient fertilizer use of wheat has been carried out in the temperate climates of developed countries such as those of the Mediterranean Region (Garrido-Lestache et al., 2004; Lopez-Bellido et al., 2000).

Triticale is the product of a cross between wheat and rye and the first successful human-made cereal (Carney, 1990). The high protein content of triticale is advantageous for fulfill the nutritional requirements of small ruminants and poultry (Everingtona and Givensa, 1990; Belaid, 1994). The grain protein concentration of triticale responds well to N fertilization (Detje, 1988; Cimrin et al., 2004). However, there is little information about the effects of N fertilization levels on triticale in semiarid climates. The aim of the present study was to determine the effects of N fertilizer levels on the grain yield, protein content, and protein yield of triticale cultivars.

MATERIALS AND METHODS

Field experiments were conducted in 2004/2005 and 2005/2006 at research fields of the Faculty of Agriculture of Eskisehir Osmangazi University, Turkey on the calcareous soil of dry land fallow-wheat

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Table 1. Total precipitation and temperature for 30-year average (LYA) and for 2004/05, 2005/06 at experiment field.

Month	Total rainfall (mm)			Mean temperature (℃)			Relative humidity (%)		
	2004-05	2005-06	LYA	2004-05	2005-06	LYA	2004-05	2005-06	LYA
October	5.8	47.5	25.6	12.8	12.6	11.9	59.4	71.1	66
November	15.1	16.8	30.5	5.7	3.9	6.6	67.9	68.5	74
December	26.2	6.8	48.1	1.4	-0.7	2.0	75.8	70.1	80
January	19.4	42.2	39.9	2.1	0.0	-0.2	74.3	74.1	80
February	47.5	14,2	33.9	1.5	1.5	1.2	65.9	68.1	77
March	48.3	24	36.6	4.9	5.4	4.6	62.0	63.0	70
April	38.3	25	39.2	10.0	7.5	10.1	52.6	54.7	64
May	53.6	65,6	46.2	14.7	17.8	15.0	56.6	49.1	63
June	33.8	58,6	33.5	18.2	20.8	18.7	50.3	47.9	60
July	48.5	-	13.4	22.4	23.8	21.5	48.4	40.0	54
Total	336.5	300.7	346.9						
Mean				9.4	9.2	9.1	61.3	60.6	68.8

Table 2. Analysis of variance for effects of year, cultivar and N levels on grain yield, protein content and protein yield of triticale in two years (mean square).

Source	d.f.	Grain yield	Grain protein content	Protein yield
Year (Y)	1	6.732**	8.120ns	0.073*
N level (N)	4	2.100**	61.057**	0.206**
Y x N	4	1.357**	9.441**	0.055**
Cultivar (C)	5	1.035**	2.011ns	0.025**
Y x C	5	1.507**	7.727**	0.016**
N x C	20	0.916**	3.499**	0.028**
Y x N x C	20	0.436**	3.471**	0.015**

areas of Central Anatolia (39°48′ N, 30°31′ E, 789 m elevation). Six winter hegzaploid triticale cultivars were used in these experiments: Tatlicak, 97; Presto, 2000; Karma, 2000; Melez, 2001; Mikham, 2002 are registered in Turkey and Samur Sortu in Azerbaijan. Sowing was done in the second week of October with a seed planter.

The soil samples (0 - 30 cm) were taken at seeding, air-dried, passed through a 4 mm sieve, and analyzed for pH, $CaCO_3$, organic matter and texture using a standard procedure (Rowell, 1996). Some of the properties of the soils where experiments had been conducted within two years were relatively similar, all having a low water-holding capacity, alkaline (pH 8.1), containing low organic matter (1.2%), calcareous (65% $CaCO_3$) and loamy. As in most soils in Central Anatolia, the soils of the experiment sites were poor in organic matter, thus low in N supply to plants. Table 1 shows the monthly rainfall and temperatures over the second year study. Rainfall varied between years. Total annual precipitation for 2004/05 was recorded at 336.5 mm, and for 2005/06, 300.7 mm during the growing period (October - July). Mean temperature was 9.4℃ in the first year and 9.2℃ in the second year. Total annual rainfall and mean temperature over the last 30 years was 346.9 mm and 9.2℃, respectively. Precipitation distribution also differed between years and was very similar with 30 year average and 2004/05 year from March to June which is developing and filling of the grain period. However, precipitation distribution of 2005/06 year was different with that of 30 year average.

The experimental design was a randomized complete block design with four replicates. The sowing rate was 450 seeds per m^{-2} and all cultivars were fertilized with phosphorus fertilizer at a sowing rate of 60 kg ha^{-1} P_2O_5 (as a form of triple superphosphate 0 - 46 - 0). Nitrogen fertilizer (NH_4NO_3) was pplied in early spring using a range from 0-160 kg N ha^{-1}. The levels were: N_0 (control), N_1 (0+40 kg ha^{-1}), N_2 (40+0 kg ha^{-1}), N_3 (40+40 kg ha^{-1}) and N_4 (80+80 kg ha^{-1}). Half of the N was applied at the time of sowing with the remaining half applied during the tillering stage GS 21 (Zadoks et al. 1974). Each plot (7.5 m^2) consisted of six rows, and the space between the rows was 25 cm. The plants were harvested in July. At harvest, a 0.5 m^2 portion at the center of each triticale plot was sampled. Grain yield was determined and the N content of the grain was determined by the Kjeldahl digestion method, which was then multiplied by 6.25. The grain protein yield was calculated by multiplying grain yield by grain protein content.

RESULTS AND DISCUSSION

Grain yield

The effect of N fertilizer levels (N), cultivars (C), year (Y) and their interactions (NxY, YxC, NxC and YxNxC) on grain yield were statistically significant ($P < 0.01$) (Table 2). The grain yield of triticale was higher in 2004/2005 than in 2005/2006 (Figure 1). Grain yield increased as the amount of N was increased from the control level to N_3, and decreased at N_4. The highest grain yield was obtained from N_3 application. The grain yield did not differ significantly in N_1 and N_2 levels, which had the same total N (40 kg/ha), only the application time (N_1 was at seeding and that of N_2 was top dressed) was different. Grain yield was the highest among the six triticale cultivars in Melez, 2001 over the two years (Figure 1). Samur Sortu cv. recorded the highest value (4.8 t/ha) at N_3 level in the first year, and Mikham, 2002 had the highest grain yield at N_2 level in the second year (Figure 2). The total precipitation of the first year (336.5 mm) was higher than that of

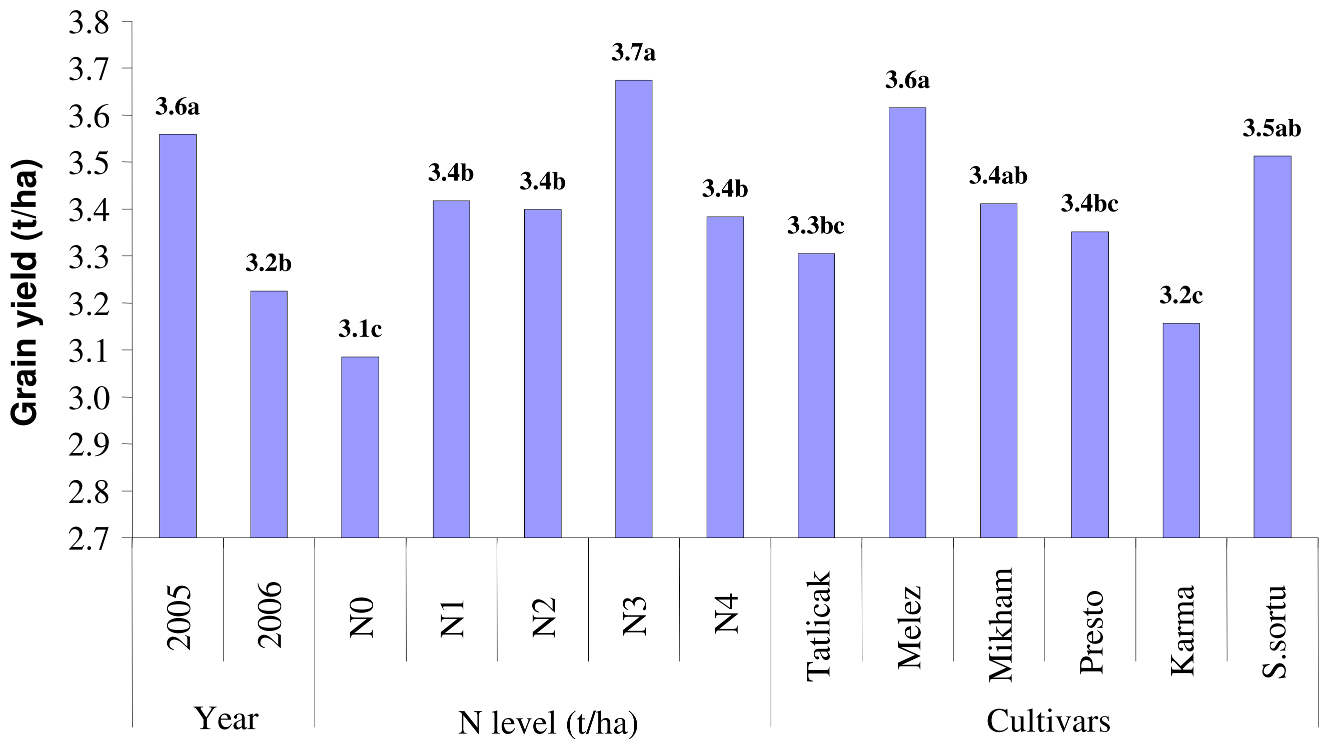

Figure 1. Triticale grain yield as affected by year, N level and cultivars over 2 years. The same letters are not significantly different at P < 0.01 according to LSD.

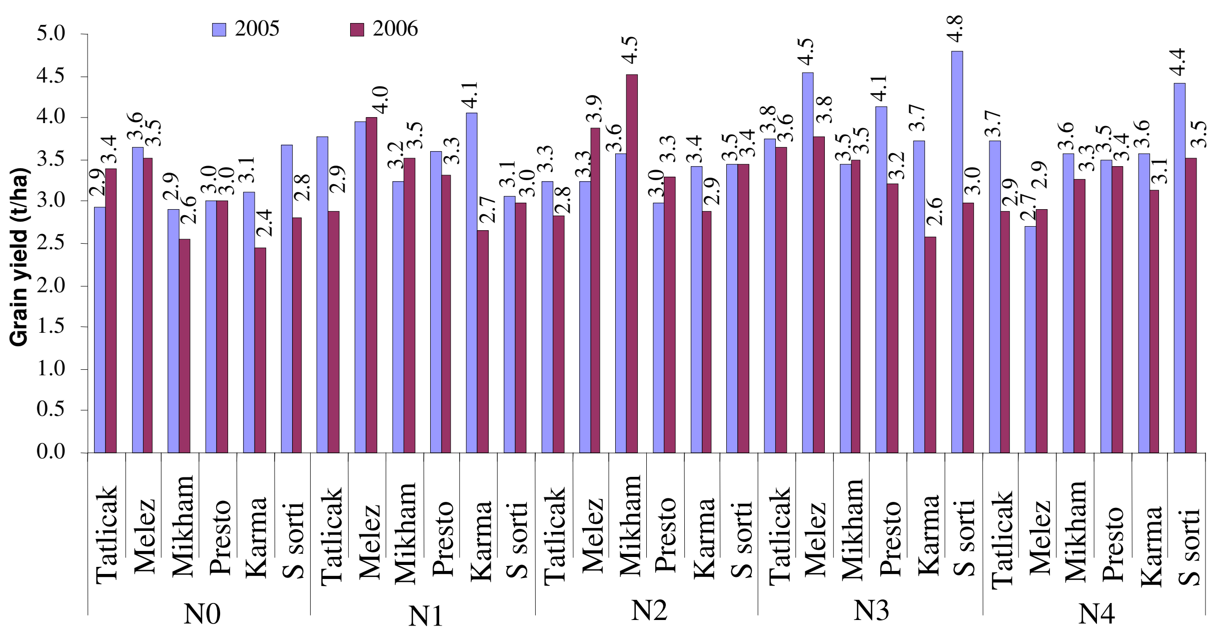

Figure 2. Grain yield of triticale cultivars at different N levels in two years.

second year (300.7 mm). The distribution of precipitation from February to June of the year 2004/05 (202.8 mm) was higher and more uniform than that of the year 2005/06 (187.4 mm) (Table 1). The distribution and amount of precipitation had an effect on the grain yield of triticale.

Royo and Blanco (1998) and Santiveri et al. (2002) explained that insufficient precipitation during the growing

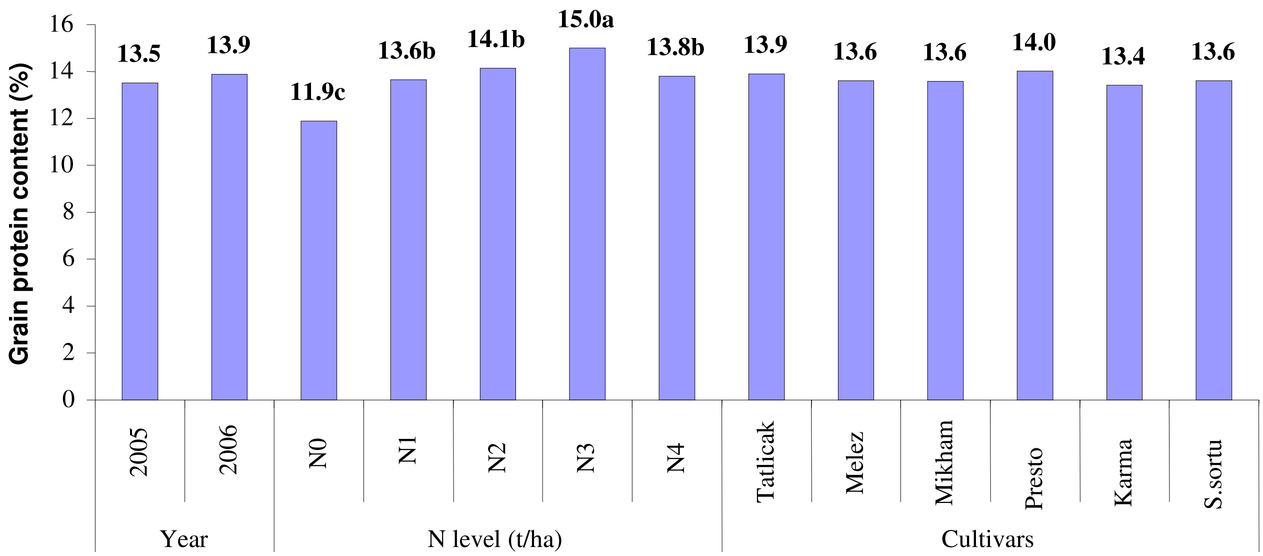

Figure 3. Triticale grain protein content as affected by N level over 2 years. The same letters are not significantly different at P < 0.01 according to LSD.

season decreases grain weight by reducing translocation of assimilates to the developing kernels. The effects of weather conditions after the topdressing are very important. The precipitation amount after topdressing in this study was higher in first year compared to second year. In addition, the amount of soil available N and the effect of rainfall distribution and amount on the mineralization of organic matter and on crop residues caused a difference in grain yield. These results agree with those reported by Lopez-Bellido et al. (1998; 2001), Topal et al. (2003), Garrido-Lestache et al. (2004) and Gulmezoglu and Kinaci (2005).

Grain protein content

The N level, interaction of YxN, YxC, NxC, and the triple interaction YxNxC were highly significant ($P < 0.01$). However, year and cultivar were not significant on protein content (Table 2). Grain protein content showed a highly significant response to N level, increasing with rising N levels till N_3 level (15%) (Figure 3). Thus, maximum grain protein content was obtained with N_3 and also this N level achieved the maximum grain yield (Figures 1 and 3). Gooding and Davies (1997) found that grain protein content did not respond consistently to increases in N level. Consequently, from N_3 upwards there is no increase in protein percentages and grain ceases to act as a sink for the N. In this case, fertilizer N application is uneconomical, since it prompts a luxury uptake of N, in excess of yield requirements, and also gives rise to the potential problems of leaching and the runoff of nitrates (Garrido-Lestache at al., 2004; Bergström and Kirchmann, 2006).

There were no significant differences among cultivars for protein content, however, there was a significant NxC interaction (Table 2), and Melez, 2001 had the highest protein content (18%) at N_3 application in the first year (Figure 4). Triticale cultivars showed a different response to the N level. Positive responses to increasing N have been associated with an increase in grain protein content. This was confirmed by Kara and Uysal (2009), who were determined a positive connection between grain yield and protein content of triticale. Banziger et al. (1992) reported that genotypic variability in grain protein content may be affected not only by physiological traits but also by N supply in the soil. Also, our findings that protein content varied among the investigated cultivars confirms those of Zhu et al. (1991), who reported variation in wheat varieties.

Grain protein yield

The year ($P < 0.05$), N level, cultivar, interaction of Yx N level, YxC, NxC and the triple interaction YxNxC were highly significant ($P < 0.01$) (Table 2). Protein yield increased with rising N levels till N_3 level (0.551 t ha^{-1}). Protein yields were little affected by the N_4 increment of N in comparison with the control (Figure 5). There were significant differences among cultivars for grain protein yield. With the exception of Karma, 2000, the other cultivars had the same statistical significance over the two year period (Figure 5). The protein yields of Melez, 2001 (0.79 t ha^{-1}) in 2004/05 and Mikham 2000 (0.65 t ha^{-1}) in 2005/06 were the highest of all of the cultivars (Figure 6).

Nitrogen levels generally affected crop growth,

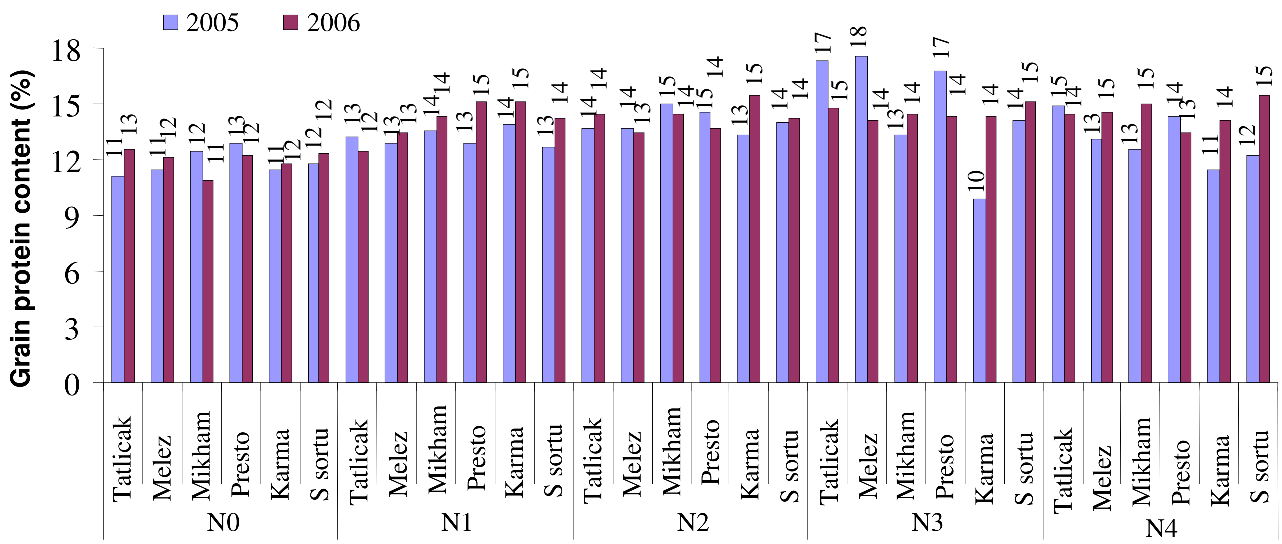

Figure 4. Grain protein content of triticale cultivars at different N levels in two years.

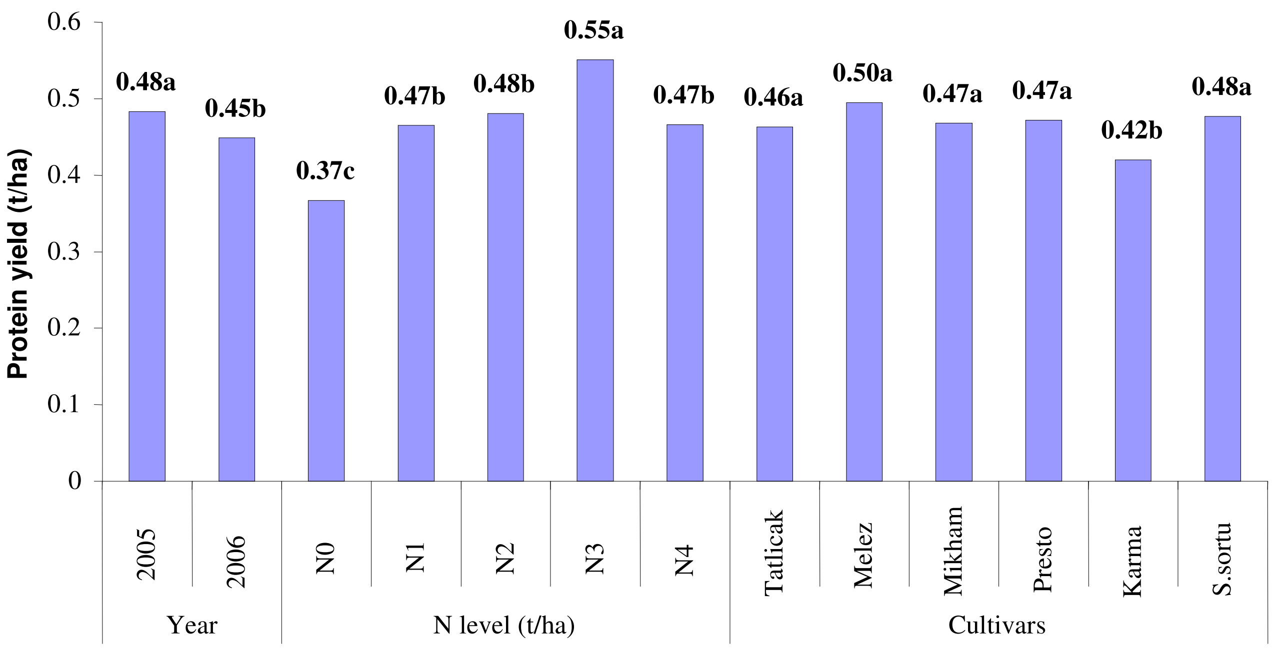

Figure 5. Triticale protein yield as affected by year, N level and cultivars over 2 years. The same letter are not significantly different at P < 0.05 for year; P < 0.01 for N and cultivars according to LSD.

increased grain protein content, and finally increased grain yield and grain protein yield till N_3 level. Grain protein content did not respond consistently to increases in N level. This finding was similar to Garrido-Lestache et al. (2004). The highest grain yield and protein yield for triticale being at N_3 level for the two-year study demonstrated that there was a positive relationship between grain protein content and grain yield. As a result, this study did not detect a negative relationship between grain protein yield and grain yield due to the effect of N dilution, as reported by Halloran (1981), Bhatia and Rabson (1987), Stoddard and Marchall (1990).

Conclusion

As a general observation relating to all parameters included in this study, there were differences between

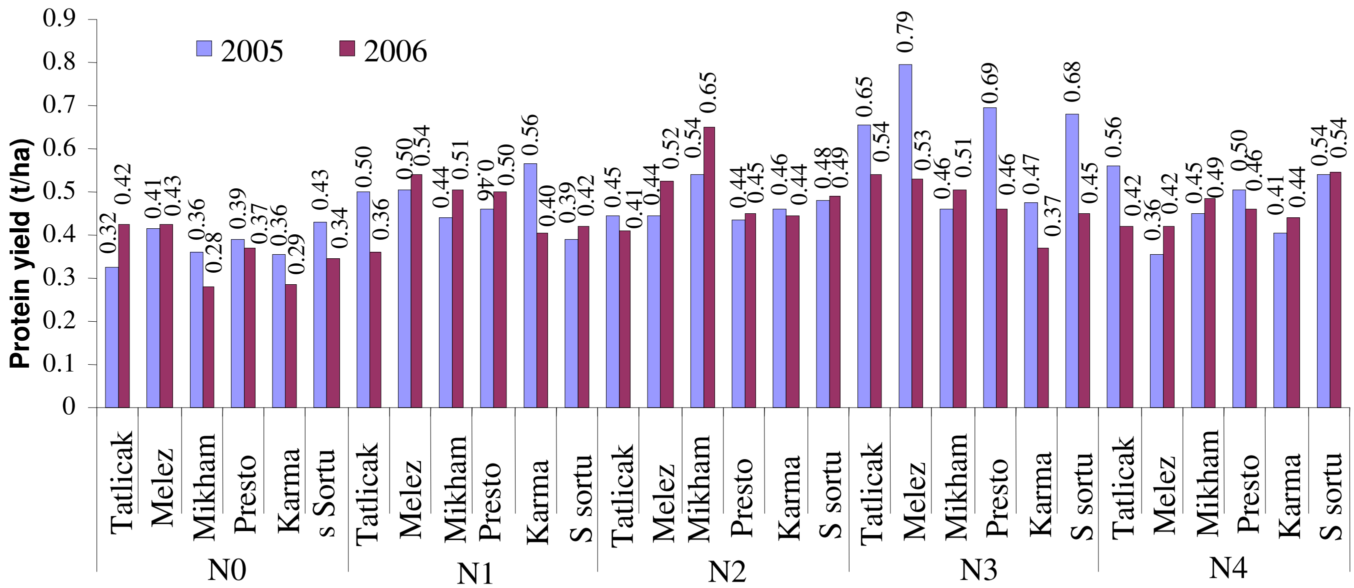

Figure 6. Protein yield of triticale cultivars at different N levels in two years.

cultivars in response to variation in N level. They were always similar in trend, but varied in N level and between years in grain yield and protein yield. This probably reflected the genotypic differences in gene regulations in response to N levels and other growth conditions. In conclusion, grain yield, protein content and protein yield were highest at N_3 (40+40 kg ha^{-1}) level. The grain yield of triticale did not differ at N_1 and N_2 (0+40 and 40+0 kg N ha^{-1}) levels depending on the application time. Melez,2001 cultivar produced higher performance than the other triticale cultivars. The high protein content and yield of triticale cultivars may be advantageous for the nutritional requirements of small ruminants and poultry.

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