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THE EFFECTS OF THE LEVEL AND TIMING OF NITROGEN FERTILİZATION ON THE GRAIN YIELD AND QUALITY OF IRRIGATED WINTER DURUM WHEAT

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ABSTRACT

To improve grain yield and quality of irrigated winter durum wheat (Triticum durum L. cv. Kızıltan-91), this study was conducted to determine the optimal amount and timing of nitrogen fertilization. Experiments were carried out in 1997-98 and 1998-99 growing seasons with irrigated winter durum wheat in Konya Region, Central Anatolia, Turkey. The amounts of nitrogen were 50, 100, 150 and 200 kg N ha^{-1} versus control. Timings of nitrogen were "the all at sowing", "1/2 at sowing + 1/2 at stem elongation", and "1/3 at sowing + 1/3 at stem elongation + 1/3 at boot stage".

The highest grain yield was obtained with the applications of 150 kg N ha^{-1} increasing from 3490 and 3060 kg. ha^{-1} to 4540 and 4150 kg. ha^{-1} in 1997-98 and 1998-99 seasons, respectively (P<0.01). Split applications of nitrogen increased the grain yield over the single application, the all at sowing. Grain yield for the two seasons were 4380 and 4050 kg ha^{-1} in the third application timing while it was 3870 and 3600 kg ha^{-1} in the first application timing (all at sowing), respectively (P<0.01). Protein concentration was increased (3 %) by nitrogen application. Split application of nitrogen increased (1 %) protein concentration over single application.

Keywords: *Durum wheat, nitrogen applications, grain yield, quality*

SULU KOŞULLARDA KIŞLIK MAKARNALIK BUĞDAYDA AZOT MİKTARI VE UYGULAMA ZAMANININ VERİM VE KALİTE ÜZERİNE ETKİSİ

ÖZET

Bu araştırma sulu koşullarda kışlık makarnalık buğdayın (Triticum durum L. cvs. Kızıltan-91) verim ve kalitesini geliştirmek için optimum azot dozu ve uygulama zamanını belirlemek için yapılmıştır. Araştırma 1997-1998 ve 1998-1999 sezonlarında olmak üzere Konya ekolojik şartlarında iki yıl süreyle yürütülmüştür. Araştırmada beş farklı azot dozu (kontrol, 50, 100, 150 ve 200 N kg/ha) ve üç farklı uygulama zamanının (1. tamamı ekimde 2. ½ ekimde + ½ sapa kalkma döneminde 3. 1/3 ekimde + 1/3 sapa kalkmada + başaklanma öncesi) etkisi incelenmiştir.

İlk ve ikinci üretim yıllarında, sırasıyla en yüksek tane verimi kontrole göre 3490 kg/ha'dan 4540 kg/ha'a ve 3060 kg/ha'dan 4150 kg/ha'a yükselmiş, en yüksek verim artışı 150 kg N/ha uygulamasından elde edilmiştir (P<0.01). Azotun tamamının ekimde verilmesiyle birbirini takip eden üretim yıllarında sırasıyla 3870 ve 3600 kg/ha olan tane verimleri, azotun üç parça halinde verilmesiyle 4380 ve 4050 kg/ha olmuştur (P<0.01). Azot dozunun artırılması (%3) ve parçalar halinde verilmesi (%1) protein oranını artırıcı etkide bulunmuştur.

Anahtar kelimeler: *Makarnalık buğday, azot uygulamaları, tane verimi, kalite*

INTRODUCTION

Durum wheats are superior to bread wheats with respect to grain protein, gluten amount and quality. Durum wheat is needed for producing the raw material of the more complex pasta manufacturing industry. It costs commands a price due to some characteristics explained above. Annual production of durum wheat is approximately 4.5 – 5.0 million tons in Turkey (Uysal 1991). However, durum wheat production with high quality is imported each year. In this respect, both grain yield and its quality must be considered in breeding and agronomical studies. Just as Johnson (1972) expressed value on increase of 1 % of protein amount of wheat kernel was equivalant to an increase of 10 % of grain yield.

Nitrogen is the most expensive fertilizer nutrient used to raise crop plants. Therefore, it is essential to determine suitable application time and adequate amount of nitrogen for economical production and increasing of N fertilizer efficiency. Many workers determined that N increased grain yield and optimum N doses changed from 90 kg ha^{-1} to 227 kg ha^{-1} in the field trials carried out in different locations (Nourafza and Langer, 1979; Shah et al., 1994; Fatima et al., 1992; Wells et al., 1993; Nedelciuc et al., 1995; Dogan et al. 1997; Delogu et al., 1998). In a field trial with durum wheat varieties by Sade (1991) in Konya ecological conditions, it was suggested that 160-200 kg N ha^{-1} for Çakmak-79 variety and 80-120 kg N ha^{-1} for Kunduru-1149 variety as a suitable N doses. It is explained that N applications increased two protein fraction, glutenin and gliadins named gluten which have high molecular weight (Ayoub et al. 1994). The enviromental factors have a important role on N use efficiency. Over winter loss of nitrate through denitrification and leaching are the most important causes of reduced N use efficiency. Several studies have demostrated that the importance of time of N application for optimal wheat yield, increased grain protein concentration and reduction in N loss from the soil-plant system.

The timing of nitrogen applications for optimal wheat yield and high quality are quite important. Smith et al., (1989) have determined that in application of N at sowing, the plants have taken up only 40 % of applied N, in application of N at heading assimilated 66 % of applied N. 70-90 % of the N in the grain comes from storage in vegetative structures in preanthesis (Auistin et al., 1977). Nevertheless, a higher N remobilization enhanced the senescence of tissues (Sinclair and Wit, 1975; Mitra and Bathia, (1984) and resulted in lower grain yields. In that case split applications become important for high grain yield and grain protein concentration.Tiryakioglu et. al. (1999) have determined that late nitrogen application increased the grain protein content of varieties by 4.3 – 28.3 % and nitrogen application at late season resulted in a decrease in the grain yield generally. Some researchers have found that split applications had no effect on grain yield and protein concentration (Ignatova and Petkova, 1985; Yıldırım and et al. 1997).

Grain yield and grain protein amount which are influenced by environmental and cropping factors are quantitative and have a quite complex inheritance. Besides varieties with high yield and quality are improved by breeding studies, simultaneous improvement in the two characteristics could be investigated on cropping techniques. This study was carried out to determine the effect of timing and amount of nitrogen fertilizer on the yield and quality of irrigated winter durum wheat.

MATERIALS AND METHODS

Field experiment was conducted under irrigated conditions at the research area of Faculty of Agriculture of Selcuk University in 1997-98 and 1998-99 cropping seasons. The field is an altitude of 1031 m in Konya Region (36.5^0–39.5^0 N, 31.5^0–34.5^0 E), Central Anatolia, Turkey. Total annual precipitation during 1997-98 and 1998-99 was 355.7 mm and 301.3 mm while it was 316.6 mm as a mean of long–term. The wheather in the spring 1998-99 cropping season was drought while the rains were very high in the autumn and winter season. The mean of temperature (from September to July) was 9.4 ^{0}C and 11.4 ^{0}C during 1997-98 and 1998-99, respectively, while it was 9.3 ^{0}C as a mean of long–term. The mean of relative humidity was 58.6 % and 55.5 % during 1997-98 and 1998-99, respectively while it was 62.3 % as a mean of long – term. Soil samples were taken in the depth of 0-60 cm at planting time and analyzed for some parameters by procedures used at the Soil Science Labarotory of Faculty of Agriculture. Soil texture was clay loamy, organic matter was 2.5 %, $CaCO_3$ was high (41 %) and pH was 7.80. There was no salinity. Available K was rich (1140 kg K_2O ha^{-1}) Mineral nitrogen content of the experimental soil was 0.084 %.

Kızıltan-91, durum wheat cultivar has been used as material. The experimental design was Factorial in Randomized Complete Block Design with three replications comprising five nitrogen treatments (control, 50, 100,150 and 200 kg N ha^{-1}) and three timing of nitrogen (I. The all at sowing, II.1/2 at sowing + 1/2 at stem elongation and III. 1/3 at sowing + 1/3 at stem elongation + 1/3 at boot stage). Planting was done on the 16 October 1997 and 27 October 1998 at a seeding rate of 500 grains m^2. Each plot had six rows, 7 m in lenght and 20 cm between rows. At planting, 90 kg P ha^{-1} was applied to seed bed with an experimental drill as triple super phosphate (42-44 % P_2O_5). At planting, N was applied to seed bed as ammonium sulphate (21 % N), applied by top dressing as ammonium nitrate (33 % N) in other application timing (GS-30 and GS-45). Because the precipitation in the autumn was adequate in both years, irrigation was not done for emergence. The plots were sprinkled twice to retain the moisture content of soil in 0-90 cm rooting depht to field capacity at stem elongation (GS-30) and boot stages (GS-45). Before stem elongation (GS-30) weeds were controlled with 2-4-D-ester (1500 cc ha^{-1}).

Grain was harvested by plot machine from four rows of 5 m length in the middle of the plots in 12 July 1998 and 10 July 1999.

Grain yield, 1000 grain weight, hectoliter weight, protein concentration, wet and dry gluten concentrations were determined in all plots.

RESULTS AND DISCUSSION

Grain Yield

The effects of levels and timing of nitrogen were important statistically on grain yield in the both years but the interaction of nitrogen levels x timing was significant only in 1997-98 (Table 1).

While the grain yields were 3490 kg ha^{-1} and 3060 kg ha^{-1} in the control treatment in 1997-98 and 1988-99, it was increased up to 4540 kg ha^{-1} and 4150 kg ha^{-1} by the application of 150 kg N ha^{-1}, respectively. However, the levels of 100, 150 and 200 kg N ha^{-1} in the both years were significantly different (Table 2). It can be recommended that the application of 150 kg N ha^{-1}with respect to grain yield is enough for economical production in this ecology. Smilarly Dogan et al. (1997) determined that different nitrogen amounts applied per decare (0, 8, 12, 16, 20 kg N) changed the grain yield significantly. As the nitrogen amounts increased up to 16 kg/da level so did the grain yields, and then they stayed.

Grain yield was decreased by the application of 200 kg N ha^{-1} with respect to 150 kg N ha^{-1} in 1997-98. In this year, the grain yield observed application of 200 kg N ha^{-1} (3423 kg ha^{-1}) was lower than these of even in control plots (3493 kg ha^{-1}) at the single application timing. The results have showed that high N levels given at sowing time decreased the grain yield. Non-significant nitrogen x timing interaction in the second year can be attributed to the 40 % higher regular rainfall recorded autumn and winter in the second year than these of the first year.

Split applications of nitrogen increased the grain yield in both years. Grain yield was increased with 4200 kg ha^{-1} and 3870 kg ha^{-1} in two stages application (1/2 at sowing + 1/2 at stem elongation), 4380 kg ha^{-1} and 4050 kg ha^{-1} in three stages application (1/3 at sowing + 1/3 at stem elongation + 1/3 at boot stage) while it was 3870 kg ha^{-1} and 3600 kg ha^{-1} in all the N applied at single stage application (the all at sowing) in 1997-98 and 1998-99, respectively (Table 3). Nevertheles, the first and second application timing to take part the same yield group in both years.

Table 1. The summary of variance analysis (mean squares)

Variation Sources	DF	Grain Yield 1997-98	Grain Yield 1998-99	Protein Conc 1997-98	Protein Conc 1998-99	Wet Gluten Conc. 1997-98	Wet Gluten Conc. 1998-99
Replication	2	728.15	303.20	0.105	0.087	13.179**	4.769
Nitrogen Level (A)	4	15641.36**	18223.70**	17.347**	18.677**	276.82**	295.55**
Application Time (B)	2	10019.62**	7623.20**	2.837**	2.753**	61.414**	67.60**
A x B int.	8	1650.48*	796.70	0.306	0.595	7.773**	10.66**
Error	28	580.94	398.12	1.161	0.261	0.796	1.621
C.V. (%)		5.80	5.19	3.27	3.89	3.19	3.67

Variation Sources	DF	Dry Gluten Conc 1997-98	Dry Gluten Conc 1998-99	1000 Grain Weight 1997-98	1000 Grain Weight 1998-99	Hectoliter Weight 1997-98	Hectoliter Weight 1998-99
Replication	2	0.407	0.485	0.819	1.273	1.518	2.331
Nitrogen Level (A)	4	12.432**	17.994*	4.009	2.573	4.574**	3.501*
Application Time (B)	2	1.322**	3.844*	12.858*	0.443	2.667*	1.048
A x B int.	8	0.169	0.290	1.184	0.405	0.592	0.581
Error	28	0.082	0.179	2.352	1.578	0.693	0.981
C.V. (%)		2.79	3.77	3.53	2.90	1.04	1.24

*, ** *Significant at the 0.05 and 0.01 probability levels, respectively.*

Table 2. The effects of the level of nitrogen fertilization on grain yield and some quality characteristics of irrigated durum.

Nitrogen Levels (kg/ha)	Grain Yield (kg/ha) 1997-98	Grain Yield 1998-99	Grain Yield Mean	Protein * (%) 1997-98	Protein 1998-99	Protein Mean	Wet Gluten (%) 1997-98	Wet Gluten 1998-99	Wet Gluten Mean
0	3490 **e**[1]	3060 **e**	3280	10.37 **c**	11.11 **d**	10.74	21.96 **e**	25.56 **d**	23.76
50	4240 **c**	3870 **d**	4060	11.49 **bc**	12.25 **c**	11.87	23.88 **d**	32.83 **c**	28.35
100	4440 **b**	4090 **b**	4270	12.59 **ab**	13.57 **b**	13.08	27.29 **c**	36.48 **b**	31.88
150	4540 **a**	4150 **a**	4350	13.04 **a**	13.98 **b**	13.51	31.13 **b**	38.47 **a**	34.80
200	4040 **d**	4040 **c**	4040	13.94 **a**	14.73 **a**	14.33	35.70 **a**	39.89 **a**	37.79
Mean	4150	3842	3996	12.28	13.12	12.70	27.99	34.64	31.31
LSD	31.40	25.99		1.40	0.66		1.16	1.65	

Nitrogen Levels (kg/ha)	Dry Gluten (%) 1997-98	Dry Gluten 1998-99	Dry Gluten Mean	1000 Grain Weight** (g) 1997-98	1000 Grain Weight 1998-99	1000 Grain Weight Mean	Hectoliter Weight (kg) 1997-98	Hectoliter Weight 1998-99	Hectoliter Weight Mean
0	8.53 **e**	9.00 **e**	8.76	44.24	43.64	43.94	79.57 **bc**	78.65 **b**	79.11
50	9.82 **d**	10.68 **d**	10.25	43.77	44.12	43.94	80.85 **a**	79.62 **a**	80.23
100	10.39 **c**	11.70 **c**	11.04	43.76	43.03	43.39	80.02**abc**	80.16 **a**	80.09
150	11.00 **b**	12.11 **b**	11.55	43.10	43.11	43.10	80.57 **ab**	79.37**ab**	79.97
200	11.60 **a**	12.54 **a**	12.07	42.53	42.80	42.66	79.11 **c**	80.13 **a**	79.62
Mean	10.26	11.20	10.73	43.48	43.34	43.41	80.02	79.58	79.80
LSD	0.37	0.40		-	-		1.08	0.95	

* *Based on dry matter and N x 5.7* ** *Based on dry matter*[1]
Within columns, means followed by the same letter are not significantly different by LSD range test (P < 0.01).

Single stage application at sowing is often less effective than the split application. Shah et al., (1994) in Texas showed that spring N application in different times increased the grain yield. Decau and Pujol (1982) determined the highest grain yield when N applied at the sowing + stem elongation + heading stages as the same in this trial. On the other hand, Koshta and Raghu (1981), Akkaya (1993) explained that N applications were more suitable at the stages of sowing, tillering or sowing and stem elongation. On the contrary, some workers said that there was not a significant difference between the single application and the split application (Johnson et al., 1984) while the some other workers determined that N applied at before heading did not increase or decreased the grain yield (Zhemola and Lebedeva, 1970; Tiryakioglu et al. 1999).

Table 3. The effects of the timing of nitrogen fertilization on grain yield and some quality characteristics of irrigated durum.

Nit. Ap. Time	Grain Yield (kg/ha) 1997-98	1998-99	Mean	Protein * (%) 1997-98	1998-99	Mean	Wet Gluten (%) 1997-98	1998-99	Mean
I	3870 **c**[1]	3600 **c**	3740	11.82 **b**	12.67 **b**	12.24	25.83 **c**	32.36 **c**	29.09
II	4200 **b**	3870 **b**	4040	12.35 **ab**	13.20 **a**	12.77	28.31 **b**	35.02 **b**	31.66
III	4380 **a**	4050 **a**	4220	12.68 **a**	13.52 **a**	13.10	29.84 **a**	36.56 **a**	33.20
Mean	4150	3840	3995	12.28	13.13	12.70	27.99	34.64	31.31
LSD	24.32	20.13		0.80	0.51		0.90	1.28	

Nit. Ap. Time	Dry Gluten (%) 1997-98	1998-99	Mean	1000 Grain Weight** (g) 1997-98	1998-99	Mean	Hectoliter Weight (g) 1997-98	1998-99	Mean
I	9.99 **b**	10.77 **b**	10.38	42.41 **b**	43.20	42.80	79.54 **b**	79.88	79.71
II	10.23 **b**	11.09 a**b**	10.66	44.05 **a**	43.29	43.67	80.27 **a**	79.38	79.82
III	10.58 **a**	11.76 **a**	11.17	43.98 **a**	43.53	43.75	80.26 **a**	79.50	79.88
Mean	10.26	11.20	10.73	43.48	43.34	43.41	80.02	79.58	79.80
LSD	0.28	0.89		1.14	-		0.62	-	

Notes: *I. Application Time : All at sowing, II. Application Time: ½ at sowing + ½ at stem elongation, III. Application Time: 1/3 at sowing + 1/3 at stem elongation + 1/3 at boot stage*

* *Based on dry matter and N x 5.7* ** *Based on dry matter*

[1] *within columns, means followed by the same letter are not significantly different by LSD range test (P < 0.01).*

Grain dry matter accumulation depends on mainly photosynthates produced during grain filling (Bidinger et al., 1977; Stoy, 1979), while 70-90 % of the N in the grain comes from the storoge in vegetative structures in preanthesis (Loffler et al. 1985; Austin et al., 1977). Nevertheless, a higher N remobilization enhanced the senescence of tissues (Mitra and Bathia, 1984; Sinclair and Wit, 1975) and resulted in lower grain yields. In that case, split applications become important for increase the N use efficiency.

Protein Concentration

N fertilization markedly increased the protein concentration (Table 1). The protein concentration was 13.94 % and 14.73 % in the application of 200 kg N ha^{-1} while it was 10.37 % and 11.11 % in control in 1997-98 and 1998-99, respectively (Table 2). In a study in Canada, it was demonstrated that N fertilizer application increased protein content (Ayoub et al., 1994). Similarly Akkaya (1993) determined that N fertilizer application of 200 kg N ha^{-1} increased protein concentration over the control. Our results were also confirmed by some researchers (Christiansen and Meints, 1982).

Split application of N at stem elongation and boot stages increased grain protein concentration significantly with respect to the single stage application at sowing (Table 1). The protein content were 11.82 % and 12.67 % for the single stage application whereas they were 12.35 % and 13.20 % for two stage application ½ at sowing and ½ at stem elongation , and 12.68 % and 13.52 % for the application at three stage application (1/3 sowing + 1/3 stem elongation + 1/3 boot stage) in 1997-98 and 1998-99 seasons, respectively (Table 3). However, two and three stages application timing to take part the same protein concentration group except for the single stage N application at sowing.

N demands for synthesis of protein come from N remobilization of vegetative structures or uptake directly from soils and then assimilate (Auistin et al., 1977). Nevertheles, a higher N remobilization enhanced the senescence of tissues (Sinclair and Wit 1975) and resulted in lower grain yield. Tiryakioglu et. al. (1999) have determined that late nitrogen application incresed the grain protein content of varieties by 4.3 – 28.3 % and nitrogen application at late season resulted in a decrease in the grain yield generally. Mi et al., (2000) determined the highest protein concentration in which was applied N at sowing, at stem elongation and at heading stages. This results belonging to split N application also including the heading stage markedly increased the grain protein content as confirmed by the other many researchers (Swenson, 1982; Nankova, 1983; Sade, 1991; Halaç and Yürür, 1999).

Wet and Dry Gluten Concentration

N fertilization markedly increased the wet and dry gluten concentration (Table 1). The wet and dry gluten concentrations were 23.76 % and 8.76 % in control, whereas they were 37.79 % and 12.07 % in the application of 200 kg N ha^{-1} as a mean of the cropping years (Table 2).

Gluten, a protein substance, helps shape the product as it coagulates when is cooked. Some researchers found that nitrogen fertilizer markedly increased gluten concentration consistent the results (Stoy, 1979; Akkaya, 1993).

Split application increased the wet and dry gluten concentration over the single application (all at sowing) (Table 1). The wet and dry gluten concentration were 29.09 % and 10.38 % for the single application (at sowing), whereas they were 33.20 % and 11.17 % for the application of the 1/3 at sowing + 1/3 at stem elongation + 1/3 at boot stage as a mean of the cropping years (Table 3). Similarly, Swenson (1982) and Sade (1991) found that the split application of N increased the gluten concentration. Zhemola and Lebedeva (1970) determined that the additional N applied at heading raised it.

Nitrogen level x application timing interaction for wet gluten concentration was found to be significant in the both seasons. There was little variation among application timings in lower nitrogen levels. However, increasing nitrogen levels resulted in a increase in wet gluten concentration especially at the third applications timing. Generally there were correlations between the wet and dry glutens and the protein concentration. Wet gluten concentration is an indicater of grain water absorption and protein quality. Hence, wet and dry gluten contents and protein concentrations may be very dependable on growth conditions of the plants.

1000 Grain Weight

1000 grain weight was not affected significantly by nitrogen fertilization in the both years (Table 1). As a mean of the cropping years, 1000 grain weight was 43.94 g, 43.39 g, 43.10 g and 42.66 g in the application of 50, 100, 150 and 200 kg N ha^{-1}, respectively while it was 43.94 g in the control (Table 2). Some researchers were explained that N fertilization increased (Sade, 1991) not changed (Ghazal et al., 1997) or decreased 1000 grain weight (Prima et al., 1982).

The effect of timing of N on 1000 grain weight was significant in 1997-98 and not significant in 1998-99 (Table 1). In 1997-98, split application increased the 1000 grain weight with respect to single application. Just as, the highest 1000 grain weight was obtained from two stages application (1/2 at sowing + 1/2 at stem elongation) with 44.05 g while it was 42.41 g from that of the all at sowing in this year.

As a mean of the cropping years, 1000 grain weight was 42.80 g , 43.67 g and 43.75 g in the single stage application (the all at sowing), two stages application (1/2 at sowing + 1/2 at stem elongation and three stages application (1/3 at sowing + 1/3 at stem elongation + 1/3 at boot stage, respectively (Table 3). Increased in 1000 grain weight with three stages applications can be explained by split application raised the duraiton and ratio of dry matter accumulation.

Hectoliter Weight

The effect of N fertilization on hectoliter weight was statistically significant but small in the both years (Table 1). The highest hectoliter weight was obtained from the application of 50 kg N ha^{-1} and 150 kg N ha^{-1} in 1997-98 and 1998-99, respectively (80.85 kg and 80.16 kg). The lowest hectoliter weight was obtained from the control and the application of 200 kg N ha^{-1} in 1997-98 (79.11 kg and 79.57 kg) and the control in 1998-99 (78.65 kg).

Hectoliter weight which was used for standardizing and clasification of wheat as a quality factor. The effect of application timing of N on hectoliter weight was significant but small in 1997-98, but was not in 1998-99 (Table 1). The split application enhanced the hectoliter weight over the single application (at sowing) in 1997-98. Hectoliter weight was 80.27 kg and 80.26 kg in the two and three application times while it was 79.54 kg in the single stage application in 1997-98 (Table 3). Increased in hectoliter weight with split application can be explained by split application raised the duraiton and ratio of dry matter accumulation.

In conclusion, it is suggested that the application of 150 kg N ha^{-1} and split application of nitrogen, especially at three stages application timing (1/3 at sowing + 1/3 at stem elongation + 1/3 at boot stage) to be reached economical production with high grain yield and quality in irrigated winter durum wheat.

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