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THE EFFECT OF DIVIDED TOP-DRESSING APPLICATIONS OF DIFFERENT NITROGEN FERTILIZERS ON GRAIN YIELD AND QUALITY TRAITS IN BREAD WHEAT (*Triticum aestivum* L.)

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ABSTRACT

This study was carried out to determine the effect of different divided top-dressing applications of different nitrogen fertilizers on grain yield and quality traits of four bread wheat varieties (Selimiye, Esperia, Gelibolu and Rumeli). The experiments were conducted in a randomized split-plot design with 3 replicates during the 2017 and 2018 growing seasons. In the experiment, varieties were allotted as main plots and top-dressing applications were allotted as subplots. Five different pure nitrogen (N) top-dressing applications were done in the form of urea and calcium ammonium nitrate (CAN) at the beginning of tillering, the end of tillering, the beginning of stem elongation and the end of stem elongation stages. In the study, changes in grain yield, thousand kernel weight, test weight, protein content, wet gluten content, gluten index, Zeleny sedimentation value and delayed sedimentation value were investigated. Gelibolu variety for grain yield, Rumeli and Esperia varieties for grain quality were prominent. The considering the ease of application for grain yield and quality, 2nd application (80 kg ha^{-1} pure N in the form of urea at the beginning of tillering, 40 kg ha^{-1} pure N in the form of urea at the beginning of stem elongation) can be proposed in the years when April and May rainfalls are sufficient, and 3rd application (40 kg ha^{-1} pure N in the form of urea at the beginning of tillering, 40 kg ha^{-1} pure N in the form of urea at the end of tillering, 40 kg ha^{-1} pure N in the form of CAN at the beginning of stem elongation) can be proposed in the years when April and May rainfalls are insufficient.

Keywords: Grain yield, nitrogen, top-dressing, quality traits, *Triticum aestivum* L.

INTRODUCTION

Wheat is a strategic crop plant with the highest cultivation and production both in the world and in our country. Today, wheat is the staple food of about 50 countries in the world due to its wide adaptability, its ability to be grown in many different climatic conditions, the appropriate nutritional value of its grain, and the ease of transportation, storage and processing (Ongoren, 2013).

In the world, 808 million tons of wheat is produced on approximately 219 million ha and in Turkey, 19.7 million tons of wheat is produced on approximately 6.6 million ha (Anonymous, 2022). It is a known fact that the world's population is increasing rapidly, while cultivation areas are rapidly decreasing due to faulty practices in cultural processes such as tillage, irrigation, fertilization, spraying, erosion, industrialization and urbanization. According to the 2015 report of the United Nations Department of Economic and Social Affairs, the world population is estimated to be 9.7 billion in 2050 and 11.2 billion in 2100 (Anonymous, 2015). The only way to produce the wheat needed by the world's population is to increase unit area yields. Unit area yield in wheat is the result of the combined effects of genetic potential of the plant, environmental factors and cultivation techniques (Peterson et al., 1992; Altinbas et al., 2004). Nitrogen fertilization is one of the most effective cultivation technique applications that growers can easily control to increase unit area yield and product quality in wheat (Koc and Genc, 1990). Because it is very important to provide the plant nutrients that wheat needs during the growing season at the required time, in adequate quantities and with suitable methods in order to achieve the desired yield. In the researches, it has been determined that the share of fertilization in increase of grain yield of wheat is over 50% (Colkesen et al., 1993).

Nitrogen fertilizers have high mobility in the soil due to their high solubility. Especially in conditions of high rainfall, their mobility increases and they suffer serious losses as a result of washing in the soil. It is also known that nitrogen is lost from the soil in the form of ammonia gas. This prevents the expected benefits from fertilization (Karacal et al., 1988).

Nitrogen use efficiency in the production of all cereals (wheat, barley, rye, oats, maize, sorghum and rice) in the world is estimated at 33% (Raun and Johnson, 1999). The remaining 67% of nitrogen is lost in various ways. Low soil organic matter, unbalanced use of rapidly soluble nitrogen fertilizers at unsuitable times and methods, salinity and aridity, inadequate or excessive irrigation with unsuitable irrigation methods, late sowing, low sowing density, inadequate weed control, cultivation of the same crop pattern for many years without taking deep-rooted plants and legumes in crop rotation, few varieties with high nitrogen use efficiency are shown as the reasons for low nitrogen uptake efficiency (Karasahin, 2014). Guo et al. (2019) indicated that nitrogen utilization efficiency and top-dressing significantly impact wheat yield and grain quality.

Especially in recent years, due to global warming and climate change, the irregularity of rainfall during the wheat growing season has attracted attention. This limits the effective utilization of nitrogen top-dressings by the plants and causes the expected grain yield not to be obtained. Therefore, in order to ensure that wheat can benefit from the nitrogen to be applied in the most effective way, it can be considered as a way to reach the desired yield and product quality by dividing the nitrogen in critical growing periods by taking into account the distribution of precipitation during the growing season.

Many studies showed that divided top-dressing applications of N in wheat significantly positive affect grain yield and protein content (Avci, 2007; Dere and Koycu, 2007; Kara et al., 2009; Mutlu, 2021; Zheng et al., 2021; Zhang et al., 2021), 1000-kernel weight (Avci, 2007; Ongoren, 2013; Zhang et al., 2021), wet gluten content (Avci, 2007; Dere and Koycu, 2007; Kara et al., 2009; Zheng et al., 2021), gluten index (Avci, 2007; Kara et al., 2009), Zeleny sedimentation value (Avci, 2007; Kara et al., 2009; Zheng et al., 2021) and delayed sedimentation value (Kara et al., 2009).

Therefore, this research was conducted to determine the effect of different divided-topdressing applications of different nitrogen fertilizers on grain yield and some quality traits of bread wheat in the northwest of Türkiye.

MATERIALS AND METHODS

Selimiye and Gelibolu bread wheat varieties from Thrace Agricultural Research Institute, Esperia bread wheat variety from Tasaco Agriculture Company and Rumeli bread wheat variety from Thrace Agriculture Seed Company were used as plant materials in the research.

This research was conducted in a farmer's field in Meneksesofular Village of Edirne Province (41° 45' 47.4480" N and 26° 38' 27.0960" E, 120 m altitude) during the 2017 and 2018 wheat growing periods. During the both years, a blind experiment was established by sowing sunflower in the experimental areas without any fertilization in the previous year.

Some climatic data of the experimental location during the wheat growth period was recorded as shown in Table 1. When the long-term average data for Edirne Province between October and June were analyzed, it was found that there was an average temperature of 10.5°C, a total of 482.7 mm precipitation and a relative humidity 74.6%. The mean temperature (8.9°C), total precipitation (408.0 mm) and relative humidity (72.8%) in the first year of the experiment were lower than the long-term and the second year (12.1°C; 799.6 mm; 77.3%). Although the total rainfall in the second year of the experiment was much higher than the long-term average, it was noticed that the distribution of rainfall according to months was unbalanced. It is understood that the amount of precipitation received in April and May, when stem elongation, heading and nutrient transportation to the grain, was well below the long-term averages.

Table 1. Some climatic data of the experimental area in the 2017 and 2018 years.

Months	**Mean temperature (ºC)**			**Precipitation (mm)**			**Relative humidity (%)**		
	2016-17	2017-18	Long-term	2016-17	2017-18	Long-term	2016-17	2017-18	Long-term
October	14.3	13.6	14.1	44.4	135.2	52.9	69.5	77.1	81
November	0.7	9.5	8.5	3.2	71.6	72.4	72.9	75.7	80
December	0.7	7.4	4.2	3.2	119.6	61.7	72.9	85.1	82
January	-1.9	4.3	2.8	67.8	55.6	48.1	83.7	88.1	81
February	5.3	5.7	4.2	43.4	101.8	46.9	80.0	89.5	77
March	10.2	8.9	7.6	51.0	145.6	52.2	73.0	88.8	73
April	12.5	16.6	12.8	65.6	3.0	51.0	63.1	61.3	68
May	17.9	20.3	17.9	85.0	18.8	56.0	65.4	64.0	67
June	21.2	22.6	22.3	44.4	148.4	41.5	74.4	66.4	62
Average/Total	**8.99**	**12.1**	**10.5**	**408.0**	**799.6**	**482.7**	**72.8**	**77.3**	**74.6**

Source: Meteorological Station Data, Edirne-Turkiye

The soil characteristics between 0 and 30 cm deep in the experimental areas were given in Table 2. In the first and second year, the experimental areas were border fields with similar soil structures. It was determined that the soils of the experimental areas were clay-loam, slightly alkaline, salt-free and low in organic matter

The experiment was laid out in split-plots design with 3 replicates during the 2017 and 2018 seasons. In the experiment, bread wheat varieties were allotted as main plots and top-dressing applications were allotted as subplots. The seeds of varieties were sown by hand in plots consisting of 6 rows of 5 m and each row was 0.2 m apart. Sowing rate was 500 seeds m^{-2}. Studies have shown that 160 kg ha^{-1} of pure nitrogen should be applied in wheat cultivation in the Thrace Region in order to reach the potential wheat yield of the region (Gucdemir, 2006). Thus, 40 kg of the total 160 kg ha^{-1} pure nitrogen to be applied in the experiment was given to all plots as base fertilizer with 20.20.0 compound fertilizer at sowing. The remaining 120 kg ha^{-1} of pure nitrogen was applied manually with urea and calcium ammonium nitrate (CAN) fertilizers as top-dressing fertilizers in 5 different ways as shown in Table 3 considering the growth stages (GS; Zadoks et al., 1974) of wheat and rainfall. In the study, chemical control was applied against weeds and leaf rust diseases. All plots were harvested with a HEGE-125 combine harvester at maturity on July 01, 2017 in the first year and June 14, 2018 in the second year. After harvesting the plots, grain yield (kg ha^{-1}), 1000 kernel-weight (g), test weight (kg hl^{-1}, protein content (%), wet gluten content (%), gluten index (%), Zeleny sedimentation value (ml) and delayed sedimentation value (ml) were determined.

Table 2. Soil characteristics of the experimental areas.

	2017		2018	
Characteristics	**Value**	**Class**	**Value**	**Class**
Texture	-	Clay-loam	-	Clay-loam
pH	7.70	Slightly alkaline	7.14	Slightly alkaline
EC, mm/cm	836.00	Low	800.00	Low
$CaCO_3$, %	3.17	Low	1.59	Low
Organic matter, %	1.38	Low	1.41	Low
Nitrogen (N), %	0.07	Low	0.07	Low
Phosphorus (P), ppm	7.21	Low	16.00	Low
Potassium (K), ppm	284.94	High	399.00	High
Sodium (Na), ppm	8659.43	Sufficient	7848.47	Sufficient
Iron (Fe), ppm	12.28	High	11.98	Medium
Copper (Cu), ppm	1.68	Sufficient	1.48	Sufficient
Zinc (Zn), ppm	1.01	Low	0.96	Low
Manganese (Mn), ppm	8.15	Low	7.65	Low

Table 3. Top-dressing applications.

	Top-dressing application stages			
Applications	**The beginning of tillering (GS 21)**	**The end of tillering (GS 25)**	**The beginning of stem elongation (GS 31)**	**The end of stem elongation (GS 37)**
1st	80 kg ha^{-1} pure N (urea)	-	40 kg ha^{-1} pure N (CAN)	-
2nd	80 kg ha^{-1} pure N (urea)	-	40 kg ha^{-1} pure N (urea)	-
3rd	40 kg ha^{-1} pure N (urea)	40 kg ha^{-1} pure N (urea)	40 kg ha^{-1} pure N (CAN)	-
4th	80 kg ha^{-1} pure N (urea)	-	20 kg ha^{-1} pure N (CAN)	20 kg ha^{-1} pure N (CAN)
5th	40 kg ha^{-1} pure N (urea)	40 kg ha^{-1} pure N (urea)	20 kg ha^{-1} pure N (CAN)	20 kg ha^{-1} pure N (CAN)

After checking the normality of the data distribution, data from each year were analyzed separately after verifying the significant effect of the "year of experiment" (i.e., 2017 and 2018) as an explanatory variable regarding the studied traits. Analysis of variance (ANOVA) for all examined traits were performed according to split-plots design using the JMP statistical software. The means were compared using the LSD (least significant difference) test at the 5% probability level (Steel and Torrie, 1980).

RESULTS AND DISCUSSION

The results of analysis of variance for the effects of variety and top-dressing application and their interactions on investigated traits were given in Table 4. Besides, mean values and significance group of variety, top-dressing applications and their interaction were given in Table 5 and Table 6.

Grain yield (kg ha^{-1})

The effect of variety, top-dressing application and variety x top-dressing application interaction on grain yield were statistically significant ($p \leq 0.01$) in both years (Table 4). The mean grain yields of the varieties varied between 5745.6-6116.2 kg ha^{-1} in the first year and 3677.9-4121.2 kg ha^{-1} in the second year (Table 5). The highest mean grain yield was determined in Gelibolu variety in 2017 and in Esperia variety in 2018. In the first experimental year, the mean grain yield of top-dressing applications varied between 5736.2-6070.8 kg ha^{-1}. The highest grain yield was obtained from the 2nd application, followed by the 4th application (5977.4 kg ha^{-1}) in the same statistical group (Table 5). In the second experimental year, grain yield means obtained from top-dressing applications varied between 3737.5-4027.9 kg ha^{-1}. The 3rd application had the highest grain yield value, followed by the 5th application (3981.5 kg ha^{-1}) in the same statistical group (Table 5). In variety x top-dressing application interaction, the highest grain yield was determined in the 2nd application of Gelibolu variety (6760.4 kg ha^{-1}) in 2017, and in the 3rd application of Esperia (4608.3 kg ha^{-1}) in 2018 (Table 6).

According to results of this study, it is noteworthy that the grain yields obtained in 2017 were considerably higher than the grain yields obtained in 2018. This may be due to the difference in the amount of precipitation received in April and May, especially in stages of stem elongation, heading and grain filling, between the years. In the second year of the experiment, wheat plants may have been under agricultural drought stress.

It was observed that the grain yield performances of the varieties were different depending on the years of the experiment. In the first year of the experiment, Gelibolu variety and in the second year Esperia variety stood out with high grain yield values. Similar to our findings, it was determined that there were significant differences between the grain yields of wheat varieties in many studies (Kahriman and Egesel, 2011; Ongoren, 2013; Aydogan and Soylu, 2017).

In our study, it was determined that the effect of different nitrogen top-dressing applications on grain yield varied depending on years. Similar to our findings, Gokmen et al. (2001) reported that the effect of nitrogen fertilizer application on grain yield varied depending on genotype and year. In the first year of the experiment, 2nd and 4th applications had the highest grain yield. In this year, it is noteworthy that regular rainfall was received in April and May, which include the stages of stem elongation, heading and grain filling of the plants. Especially, in the 2nd application, the nitrogen given in the form of urea, which has a slower release than CAN fertilizer, was lost less and the plants benefited from this nitrogen more effectively. On the other hand, in the second year of the experiment, 3rd and 5th applications had higher grain yield values. In 2018, the total precipitation received in April and May (21.8 mm), which includes the stages of stem elongation, heading and grain filling of the plants, was much lower than the long-term average (107 mm). Under these limited rainfall conditions, unlike the other applications, in the 3rd and 5th applications, especially during the tillering period, the application of top-dressing fertilizer in two equal amounts allowed the plants to utilize nitrogen more efficiently. Thus, it was possible to obtain higher grain yield from these applications compared to the other applications. These results indicate that it would be appropriate to divide the total nitrogen to be given during the tillering period into two equal amounts, one at the beginning of tillering and one at the end of tillering, especially in years with limited rainfall in April-May. Our findings are consistent with the findings of Kara et al. (2009), Allart et al. (2023), Gaile et al. (2023), Hamani et al. (2023), Yao et al. (2023), who reported that grain yield of wheat was significantly affected by different nitrogen top-dressing applications.

1000-kernel weight (g)

In both years of our study, variety and top-dressing application had a significant effect ($p \leq 0.01$) on 1000-kernel weight, while the effect of variety x top-dressing application interaction was not significant (Table 4). The mean 1000-kernel weight of the varieties varied from 38.73 g to 47.09 g in the first year of experiment and 40.55 g to 46.72 g in the second year of experiment (Table 5). In the first year, Gelibolu variety had the highest 1000-kernel weight, followed by Selimiye variety (46.11 g) in the same statistical group. In the second year, the highest 1000-kernel weight obtained from Selimiye variety, followed by Gelibolu variety (43.31 g) (Table 5). The mean 1000-kernel weight of top-dressing applications varied between 42.37-44.62 g in the first year of experiment. The fifth application had the highest 1000-kernel weight, followed by 3rd application with 43.62 g in the same statistical group (Table 5). In the second year of experiment, the mean 1000-kernel weight of top-dressing applications ranged from 41.80 g to 44.10 g. The highest 1000-kernel weight was determined in the 5th application, followed by 3rd application with 43.88 g in the same statistical group (Table 5).

Table 4. The results of analysis of variance for investigated traits in the 2017 and 2018 years

		Mean of squares							
SV	**DF**	**Grain yield**	**1000-kernel weight**	**Test weight**	**Protein content**	**Wet gluten content**	**Gluten index**	**Zeleny sedim. value**	**Delayed sedim. value**
		2017							
Replication	2	488.08	5.23	0.59	0.09	0.82	3.15	0.72	1.22
Variety (V)	3	4194.68**	238.49**	22.73**	7.15**	36.34**	1633.97**	1062.84**	4569.26**
Error-1	6	282.73	2.30	0.46	0.36	0.86	4.04	3.43	1.66
Application (A)	4	2536.94**	9.21**	0.41	2.71**	18.81**	15.19*	196.73**	331.06**
VxA	12	2757.57**	4.09	0.38	0.18	3.38**	105.74**	31.58**	188.53**
Error	32	228.72	2.18	0.39	0.14	0.74	3.96	2.60	1.63
Total	59								
		2018							
Replication	2	195.51	5.53	1.52	0.03	0.92	0.32	5.07	1.95
Variety (V)	3	5527.27**	116.67**	18.44**	13.65**	145.15**	762.20**	807.39**	2118.09**
Error-1	6	57.38	1.56	0.37	0.08	0.27	0.92	4.38	2.37
Application (A)	4	1679.18**	12.17**	0.51	1.50**	12.13**	142.93**	155.92**	87.73**
VxA	12	1356.74**	1.44	0.13	0.12	3.17*	74.31**	14.95*	9.87**
Error	32	75.84	1.15	0.20	0.19	1.15	2.77	7.15	2.62
Total	59								

SV: source of variation; DF: degree of freedom; Sedim.: sedimentation; *, ** significant at 5% and 1% levels, respectively

Table 5. Mean values and significance groups of variety and top-dressing applications for investigated traits in the 2017 and 2018 years

Years	Grain yield (kg ha^{-1})	1000-kernel weight (g)	Test weight (kg hl^{-1})	Protein content (%)	Wet gluten content (%)	Gluten index (%)	Zeleny sedim. value (ml)	Delayed sedim. value (ml)
2017	5888.4 a	43.27	78.88 b	13.16 a	30.23 a	84.45 b	49.07 a	33.68 b
2018	3899.7 b	42.93	79.09 a	10.98 b	20.58 b	91.57 a	40.58 b	55.20 a
LSD $_{(P\leq0.05)}$	*46.5*	-	*0.170*	*0.150*	*0.340*	*0.670*	*0.840*	*0.670*
2017								
Varieties								
Selimiye	5745.6 c	46.11 a	79.10 b	12.49 c	29.90 b	69.93 d	40.87 d	15.13 d
Esperia	5782.7 bc	38.73 c	77.08 c	13.43 b	29.77 b	93.47 a	55.00 b	36.13 b
Gelibolu	6116.2 a	47.09 a	79.61 ab	12.73 c	28.81 c	84.07 c	42.87 c	27.00 c
Rumeli	5909.2 b	41.16 b	79.72 a	14.01 a	32.45 a	90.33 b	57.53 a	56.47 a
LSD $_{(P\leq0.05)}$	*150.23*	*1.355*	*0.609*	*0.537*	*0.828*	*1.795*	*1.654*	*1.151*
Applications								
1st	5909.9 b	42.98 bc	78.68	13.32 a	30.42 bc	83.25 b	48.50 c	29.83 d
2nd	6070.8 a	42.78 bc	78.97	13.30 a	30.20 c	85.42 a	50.00 b	28.42 e
3rd	5747.9 c	43.62 ab	78.80	13.51 a	31.44 a	84.83 a	54.75 a	41.42 a
4th	5977.4 ab	42.37 c	78.79	12.32 b	28.17 d	83.25 b	43.42 d	32.50 c
5th	5736.2 c	44.62 a	79.16	13.34 a	30.94 ab	85.50 a	48.67 bc	36.25 b
LSD $_{(P\leq0.05)}$	*125.76*	*1.226*	-	*0.312*	*0.716*	*1.655*	*1.341*	*1.062*
2018								
Varieties								
Selimiye	3821.7 c	46.72 a	80.05 a	10.85 c	21.91 b	93.80 c	37.73 c	48.33 c
Esperia	4121.2 a	41.15 c	77.50 c	11.20 b	19.65 c	96.47 a	42.07 b	62.53 b
Gelibolu	3978.3 b	43.31 b	79.28 b	9.78 d	16.76 d	81.00 d	32.60 d	42.27 d
Rumeli	3677.9 d	40.55 c	79.53 ab	12.09 a	24.01 a	95.00 b	49.33 a	67.67 a
LSD $_{(P\leq0.05)}$	*67.68*	*1.116*	*0.542*	*0.255*	*0.464*	*0.855*	*1.869*	*1.376*
Applications								
1st	3824.0 c	42.30 b	79.20	10.88 bc	20.77 b	86.25 c	38.67 b	53.83 c
2nd	3737.5 d	41.80 c	78.85	10.98 b	19.76 c	93.33 a	40.00 b	55.92 b
3rd	4027.9 a	43.88 a	79.37	11.54 a	22.22 a	94.08 a	46.92 a	59.42 a
4th	3928.1 b	42.58 b	78.94	10.57 c	19.83 c	89.92 b	39.17 b	52.25 d
5th	3981.5 ab	44.10 a	79.09	10.93 b	20.34 bc	94.25 a	38.17 b	54.58 bc
LSD $_{(P\leq0.05)}$	*72.42*	*0.891*	-	*0.362*	*0.894*	*1.383*	*2.224*	*1.346*

Values followed by the same letter(s) are not significantly different at the 5% probability level according to LSD test; Sedim.: sedimentation

Table 6. Mean values and significance groups for interaction of variety x top-dressing application in the 2017 and 2018 years

Varieties	Applications	Grain yield (kg ha^{-1})	1000-kernel weight (g)	Test weight (kg hl^{-1})	Protein content (%)	Wet gluten content (%)	Gluten index (%)	Zeleny sedim. value (ml)	Delayed sedim. value (ml)
2017									
Selimiye	1st	5636.5 f	45.47	78.77	12.70	30.70 d-h	66.33 kl	43.00 fgh	8.67 n
	2nd	5593.8 f	46.67	79.72	12.73	30.47 f-ı	70.33 j	41.00 f-ı	15.00 l
	3rd	5552.0 f	45.33	78.55	12.47	31.10 c-g	63.33 l	40.33 hı	13.67 lm
	4th	5992.7 cd	44.93	78.98	11.97	28.70 k	68.00 jk	38.33 ı	12.67 m
	5th	5953.1 cde	48.13	79.48	12.57	28.53 k	81.67 h	41.67 fgh	25.67 ı
Esperia	1st	5601.0 f	36.93	77.01	13.57	28.87 jk	95.33 ab	53.00d	30.67 gh
	2nd	5953.1 cde	38.53	76.56	13.70	29.43 h-k	94.00 abc	56.00 c	21.67 k
	3rd	5753.1 def	39.60	77.32	13.97	32.03 cd	96.33 a	65.33 a	62.67 a
	4th	6089.8 c	38.87	77.23	12.23	27.07 l	97.00 a	48.67 e	32.33 fg
	5th	5516.7 f	39.73	77.26	12.87	31.47 c-f	84.67 gh	52.00 d	33.33 f
Gelibolu	1st	6433.3 b	48.53	79.43	12.67	30.23 f-j	77.33 ı	43.33 fg	25.33 ıj
	2nd	6760.4 a	44.40	79.57	12.97	28.63 k	85.00 g	43.67 f	23.33 jk
	3rd	5592.7 f	48.00	79.40	13.10	29.13 ıjk	91.33 cde	48.33 e	31.67 fg
	4th	6071.9 c	46.00	79.41	12.03	26.37 l	81.67 h	38.33 ı	25.33 ıj
	5th	5722.9 ef	48.53	80.25	12.87	29.70 g-k	85.00 g	40.67 ghı	29.33 h
Rumeli	1st	5968.8 cde	41.00	79.51	14.37	31.90 cde	94.00 abc	54.67 cd	54.67 de
	2nd	5976.0 cd	41.53	80.00	13.80	32.27 bc	92.33 bcd	59.33 b	53.67 e
	3rd	6093.8 c	41.53	79.92	14.53	33.50 ab	88.33 ef	65.00 a	57.67 bc
	4th	5755.2 def	39.67	79.53	13.07	30.53 e-ı	86.33 fg	48.33 e	59.67 b
	5th	5752.1 def	42.07	79.63	14.27	34.07 a	90.67 de	60.33 b	56.67 cd
LSD (P≤0.05)		*251.52*	-	-	-	*1.433*	*3.310*	*2.683*	*2.125*
2018									
Selimiye	1st	3766.0 ef	45.07	80.27	10.80	21.93 cd	85.33 e	36.33 fgh	47.67 ıj
	2nd	3496.9 ı	45.87	80.00	10.90	22.13 cd	96.33 ab	37.00 efg	50.67 h
	3rd	3615.6 ghı	47.47	79.83	11.10	22.63 bcd	95.00 bc	39.67 efg	50.33 hı
	4th	4061.5bc	46.93	80.07	10.33	21.00 def	96.67 ab	39.67 efg	46.67 j
	5th	4167.7 b	48.27	80.10	11.13	21.87 cd	95.67 b	36.00 gh	46.33 j
Esperia	1st	3835.4 def	41.33	77.60	11.27	19.87 fgh	95.33 bc	40.67 def	62.67 ef
	2nd	3906.2 de	40.00	77.20	11.27	19.97 efg	94.67 bc	41.00 de	64.00 de
	3rd	4608.3 a	41.87	78.03	11.87	21.73 cde	97.00 ab	50.33 b	68.00 bc
	4th	4131.2 b	40.27	77.20	10.73	18.47 ghı	96.67 ab	38.67 efg	57.67 g
	5th	4125.0 b	42.27	77.47	10.87	18.20 ghı	98.67 a	39.67 efg	60.33 fg
Gelibolu	1st	3945.8 cd	42.27	79.43	9.50	18.03 ıj	67.67 g	28.67 ı	38.33 l
	2nd	3937.5 cd	42.93	79.03	9.80	14.00 k	87.67 de	32.33 hı	42.67 k
	3rd	4185.4 b	44.67	79.70	10.33	18.10 hıj	89.33 d	40.33 efg	47.67 ıj
	4th	3917.7 cd	42.33	79.00	9.47	16.33 j	73.67 f	29.67 ı	39.33 l
	5th	3905.2 de	44.33	79.23	9.80	17.33 ıj	86.67 de	32.00 hı	43.33 k
Rumeli	1st	3747.9 fg	40.53	79.53	11.93	23.23 bc	96.67 ab	49.00 bc	66.67 bcd
	2nd	3609.4 ghı	38.40	79.17	11.97	22.93 bc	94.67 bc	49.67 b	66.33 bcd
	3rd	3702.1 fgh	41.50	79.90	12.87	26.43 a	95.00 bc	57.33 a	71.67 a
	4th	3602.1 hı	40.80	79.50	11.73	23.50 bc	92.67 c	48.67 bc	65.33 cde
	5th	3728.1 fgh	41.53	79.57	11.93	23.97 b	96.00 ab	45.00 cd	68.33 b
LSD (P≤0.05)		*144.28*	-	-	-	*1.787*	*2.766*	*4.448*	*2.692*

Values followed by the same letter(s) are not significantly different at the 5% probability level according to LSD test; Sedim.: sedimentation

In our study, it was determined that there were significant differences between the 1000-kernel weights of wheat varieties. This may be due to the genetic differences in the response of grain filling time, grain filling rate and grain size of the varieties to ecological conditions (Zheng et al., 2021). In both years of the experiment, Gelibolu and Selimiye varieties were noted with high thousand grain weights.

It was observed that the effect of nitrogen top-dressing applications on thousand grain weight was significant in both experimental years, in this study. In both years of experiment, 3rd and 5th applications had higher thousand grain weight values than other applications. This may be a result of the fact that nitrogen was divided during the tillering period unlike the other applications. Our results are in agreement with previous findings that the effect of different nitrogen top-dressing applications on 1000-kernel weight was significant (Avci, 2007; Ongoren, 2013; Zhang et al., 2021; Zheng et al, 2021; Hamani et al., 2023).

Test weight (kg hl^{-1})

In our study, test weight was significantly affected by variety, but not affected by top-dressing application and variety x top-dressing application interaction in both years (Table 4). In the first year of experiment, the mean value of test weight among varieties ranged from 77.08 kg hl^{-1} to 79.72 kg hl^{-1} (Table 5). Rumeli variety had significantly higher test weight value when compared to other varieties. This variety was followed by Gelibolu variety (79.61 kg hl^{-1}) in the same statistical group. When the results of the second year of the experiment are analyzed, it is seen that the test weight varied between 77.50-80.05 hl^{-1} for the varieties (Table 5). The highest mean test weight value was determined in Selimiye variety, followed by Rumeli variety with 79.53 hl^{-1} in the same statistical group. These results showed that Rumeli variety was prominent in terms of test weight. As it can be seen from Table 5, although the differences between them are statistically insignificant, the 5th application in the first year and the 3rd application in the second year attracted attention in terms of test weight.

The shape and size of the grain, thin or thick pericarp, deep or superficial ventral cavity are the characteristics that affect the test weight (Elgun et al., 2001). In our study, there were significant differences among the varieties for test weight. Similarly, Aydogan and Soylu (2017), and Eser et al. (2020) emphasized that there were significant differences among wheat varieties for test weight. In the present study, it was determined that there was no significant effect of different nitrogen top-dressing applications on test weight in both years. The findings of research for test weight were in agreement with Eser et al. (2020) who found that split dose nitrogen application did not present significant changes among the tested winter wheat varieties.

Protein content (%)

According to the variance analysis results of our study, the effect of variety and top-dressing applications on protein content was significant ($p \leq 0.01$) in both years, while the effect of variety x top-dressing application interaction was not significant (Table 4). In the first year of experiment, the mean protein content of varieties varied from 12.49% to 14.01%. Rumeli variety had the highest protein content, followed by Esperia variety with 13.43% (Table 5). In this year, the mean protein content values obtained from top-dressing applications varied between 12.32% and 13.51% and were grouped in two significance groups. The highest protein content was determined in the 3rd (13.51%), 5th (13.34%), 1st (13.32%) and 2nd (13.30%) applications in the same statistical group, respectively (Table 5). In the second year of experiment, the mean protein content of top-dressing applications varied from 10.57% to 11.54% (Table 5). In this year, similar to the results of the first year, the highest protein content was obtained from the 3rd treatment, followed by the 2nd and 5th applications with 10.98% and 10.93%, respectively.

Protein content in grains is largely influenced by genetics, water and nitrogen availability, biotic and abiotic stresses, and grain-filling duration (Alomari et al., 2023). Considering the years of the study, it is seen that the protein contents obtained in the first year were higher than the second year. This may be due to the difference in the rainfall received in May, which covers the milk development stage of wheat during which proteins are transported to the grains (Table 1). Similar to our results, Kara et al. (2009) determined that the protein content in wheat varied according to years and that the protein content was high in the year with high rainfall in May. In our research, it was determined that the differences between the varieties in terms of protein content were significant in both years. Our findings are similar to the results of Aydogan and Soylu (2017) and Eser et al. (2020), who found that the protein content in grain varied significantly among varieties.

In this study, it was observed that the effect of nitrogen top-dressing applications on protein content was significant in both years. The highest protein content was obtained from the 3rd treatment in both years. In the 3rd application of our study, nitrogen was divided into two equal parts during the tillering stage. Thus, the plants effectively utilized this nitrogen applied in urea form and stored nitrogen in their vegetative organs. Our results are similar to the findings of Avci (2007), Dere and Koycu (2007), Kara et al. (2009), Zheng et al. (2021), Zhang et al. (2021) and Yao et al. (2023) who found that the effect of different nitrogen top-dressing applications on the grain protein content of wheat was significant.

Wet gluten content (%)

In this study, variety, top-dressing applications and variety x top-dressing application interaction had significant effect on wet gluten content in both years (Table 4). The mean wet gluten content of varieties varied from 28.81% to 32.45% in 2017, 16.75% to 24.01% in 2018 (Table 5). Rumeli variety had significantly higher wet gluten content when compared to other varieties in both years. On the other hand, the lowest wet gluten content was obtained from Gelibolu variety in both years (Table 5). When the top-dressing applications in Table 5 are evaluated, it is seen that the wet gluten content varied between 28.17-31.44% in the first year and between 19.76-22.22% in the second year. The highest wet gluten content in top-dressing applications was obtained from the 3rd application in both years. In variety x top-dressing application interaction, wet gluten content ranged from 26.37% to 34.07% in the first year. The highest wet gluten content value was determined in the 5th (34.07%) and 3rd (33.50%) applications of Rumeli variety (Table 6). In the second year, the mean values of wet gluten content in variety x top-dressing application interaction varied between 14.00% and 26.43%. Similar to the first year, the highest wet gluten content was obtained from the 3rd application of Rumeli variety (Table 6).

Wet gluten content in wheat is an important quality criterion that provides the leavening of dough by retaining the gas formed during the fermentation of dough and has an important and positive relationship with protein content (Egesel et al., 2009). In our study, it is noticed that the values of wet gluten content obtained in the first year were higher than the second year. This may be a result of the high amount of protein transported to the grains in the first year. Similarly, Zheng et al. (2021) reported that wet gluten content varies with years.

It was determined that the wet gluten contents of the varieties used in the study were different in both years. Rumeli variety had the highest and Gelibolu variety had the lowest wet gluten content in both years. This may be due to the different genotypic characteristics of the varieties in terms of quality traits. Our results were similar with the findings of Egesel et al. (2009) and Zheng et al. (2021).

The results of the study showed that the effect of nitrogen top-dressing applications on wet gluten content was significant in both years. The highest wet gluten content was obtained from the 3rd application and the lowest wet gluten content was obtained from the 4th application in both years of experiment. This may be a result of the different protein content obtained from different nitrogen top-dressing applications. Also, the 3rd application had the highest protein content and the 4th application had the lowest protein content in this study. Demirel et al. (2023) found that there was a strong significant positive correlation between grain protein content and wet gluten content. The results of our study for wet gluten content were in accordance with the findings of Avci (2007), Dere and Koycu (2007), Kara et al. (2009), Eser et al. (2020), Zheng et al. (2021) and Gaile et al. (2023), who found that the effect of different nitrogen top-dressing applications on wet gluten content in wheat was significant.

Gluten index (%)

Data in Table 4 indicate that the gluten index is significantly influenced by variety, top-dressing applications and their interaction in both years. The mean values of gluten index for varieties varied between 69.93%-93.33% in the first year, and between 81.00%-96.47% in the second year. In both years, Esperia variety had the highest gluten index value, followed by Rumeli variety (Table 5). Gluten index values obtained from top-dressing applications were different in both years. In the first year, the mean gluten index values for top-dressing applications ranged from 83.25% to 85.50%. The highest gluten index values were determined in 5th (85.50%), 2nd (85.42%) and 3rd (84.83%) applications in the same statistical group (Table 5). In the second year of the experiment, gluten index values obtained from top-dressing applications were between 86.26% and 94.25%. Similar to the first year, the highest gluten index values were obtained from the 5th (94.25%), 3rd (94.08%), and 2nd (93.33%) applications in the same statistical group (Table 5). When the variety x top-dressing application interaction in Table 6 is analyzed, it is seen that the mean gluten index values varied between 63.33% and 97.00% in the first year and between 67.67% and 98.67% in the second year. In the variety x top-dressing application interaction, the highest gluten index values were obtained from the 4th (97.00%) and 3rd (96.33%) applications of Esperia variety in the first year and from the 5th (98.67%) application of the same variety in the second year (Table 6).

Gluten index in wheat is an important quality criterion that shows the ratio of strong proteins in wet gluten and is used to determine the quality of flour. In our study, contrary to protein content and wet gluten content, the mean values of gluten index were generally higher in the second year compared to the first year. This indicates that grains with stronger protein structure were obtained in the second year of our experiment. In the study, it was observed that the varieties had different gluten index values in both years. Esperia and Rumeli varieties had high gluten index values, while Selimiye and Gelibolu varieties had low gluten index values. Our findings are also in accordance with Egesel et al. (2009), who found that gluten index values of wheat varieties were different.

In both years of our study, the significant differences were observed among the top-dressing applications for gluten index. The highest gluten index value was obtained from the 5th application and the lowest from the 1st application. This may be due to the fact that the divided nitrogen applied especially during tillering and stem elongation periods increased the efficiency of nitrogen uptake in plants and thus the proteins accumulated in the grains had a stronger structure. Our results are supported by the results of Avci (2007), Kara et al. (2009), Erekul et al. (2012) who found that different nitrogen top-dressing applications significantly affected gluten index in wheat.

Zeleny sedimentation value (ml)

In our study, Zeleny sedimentation value was significantly affected by variety, top-dressing applications and their interaction in both years (Table 4). The varieties used in this study had Zeleny sedimentation values ranged from 40.87 ml to 57.53 ml in 2017, and from 32.60 ml to 49.33 ml in 2018 (Table 5). The highest Zeleny sedimentation value was determined in Rumeli variety, followed with Esperia variety in both years. The mean Zeleny sedimentation values obtained from top-dressing applications varied between 43.42-54.75 ml in the first year and 38.17-46.92 ml in the second year (Table 5). In both years, the 3rd application had a higher mean Zeleny sedimentation value than the other applications, followed by the 2nd application (Table 5). When the data given in Table 6 are examined, it is seen that the mean Zeleny sedimentation value in variety x top-dressing application interaction varied between 38.33-65.33 ml in the first year and 28.67-57.33 ml in the second year. In the first year of the experiment, 3rd application of Esperia (65.33 ml) and Rumeli (65.00 ml) varieties had the highest mean Zeleny sedimentation value. In the second year, the highest mean Zeleny sedimentation value was determined in the 3rd application of Rumeli variety (57.33 ml), followed by the 3rd application of Esperia variety (50.33 ml).

Zeleny sedimentation test in wheat is a practical method that provides information about gluten quantity and quality (Evlice et al., 2016). The volume of bread made from flours with high Zeleny sedimentation value is also high. In our study, the mean Zeleny sedimentation values obtained in the first year were higher than the second year. This may be a result of the high protein content obtained in the first year. Our results showed that Rumeli and Esperia varieties, which had higher protein content, wet gluten content and gluten index values than the others, had the highest mean Zeleny sedimentation values. Similar to our findings, Evlice et. al (2016), Egesel et. al (2009) and Eser et. al (2020) reported that Zeleny sedimentation values of wheat varieties were significantly different.

In our study, it was determined that the effects of different top-dressing applications on Zeleny sedimentation value were significant in both experimental years. The 3rd application had the highest Zeleny sedimentation value in both years. This may be related to the high protein content and gluten index values obtained from the 3rd application. Our results agreed with the findings of Avci (2007), Kara et al. (2009) and Zheng et al. (2021), who explained that different nitrogen top-dressing applications significantly affected Zeleny sedimentation value in wheat.

Delayed sedimentation value (ml)

Delayed sedimentation value is usually used to determine sunn pest damage in wheat. In our study, the effect of variety, top-dressing application and their interactions on delayed sedimentation value was significant in both years (Table 4). The delayed sedimentation values obtained from the varieties ranged between 15.13-56.47 ml in the first year and 28.42-41.42 ml in the second year. Rumeli variety had the highest delayed sedimentation value in both years (Table 5). The mean delayed sedimentation values of top-dressing applications varied from 28.42 ml to 41.42 ml in the first year and from 52.25 ml to 59.42 ml in the second year. The highest delayed sedimentation value was obtained from 3rd application in both years (Table 5). As seen in Table 6, the mean delayed sedimentation values obtained from the variety x top-dressing application interaction varied between 8.67-62.67 ml in the first year and 38.33-71.67 ml in the second year. The 3rd application of Esperia variety (62.67 ml) in the first year and the 3rd application of Rumeli variety (71.67 ml) in the second year had the highest delayed sedimentation value.

In our research, delayed sedimentation values obtained in the first year were lower than Zeleny sedimentation values, while delayed sedimentation values obtained in the second year were higher than Zeleny sedimentation values. This indicated that the damage caused by the sunn pest and the wheat stink bug was high in the first year of the experiment.

In our experiment, it was determined that the delayed sedimentation values of the varieties were different in both years. Rumeli variety had the highest delayed sedimentation value in both years. This result shows that Rumeli variety was less affected by the damage of the sunn pest and the wheat stink bug than the other varieties. Similar to our findings, Egesel et al. (2009), Kahriman and Egesel (2011) and Evlice et al. (2016) also reported significant differences among wheat varieties in terms of delayed sedimentation value.

In our study, the effect of different top-dressing applications on delayed sedimentation value was found significant in both years. The 3rd application had the highest delayed sedimentation value in both years. This result shows that in the 3rd application, the damage of sunn pest and wheat stink bug was lower than in the other applications. This may be a result of the high Zeleny sedimentation value obtained from the 3rd application. Because Kara et al. (2009) found a positive and significant relationship between Zeleny sedimentation value and delayed sedimentation value.

CONCLUSIONS

The results obtained in both years showed that the effect of different top-dressing applications on grain yield and quality traits (except test weight) was significant in bread wheat. In the first year of the experiment in which the distribution of precipitation to months was regular, the 2nd and 4th applications stood out in terms of grain yield, and the 3rd and 5th applications were prominent in terms of quality traits. In the second year of the experiment, in which the distribution of precipitation to months was irregular and rainfall was very low especially in April-May, the 3rd and 5th applications stood out in terms of both grain yield and quality traits.

In conclusion, the considering the ease of application for grain yield and quality, 2nd application (80 kg ha^{-1} pure N in the form of urea at the beginning of tillering, 40 kg ha^{-1} pure N in the form of urea at the beginning of stem elongation) can be proposed in the years when April and May rainfalls are sufficient, and 3rd application (40 kg ha^{-1} pure N in the form of urea at the beginning of tillering, 40 kg ha^{-1} pure N in the form of urea at the end of tillering, 40 kg ha^{-1} pure N in the form of CAN at the beginning of stem elongation) can be proposed in the years when April and May rainfalls are insufficient.

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